Prevention and Control of the Combustible Dust Threat

Chet Brandon, CSP, CHMM

Vice President, Region VII ASSP

Mid-Michigan Chapter of the ASSP

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Important Warning!

The material given in this presentation is intended for introductory training purposes only.

You are advised to utilize the assistance of knowledgeable professional technical experts in making specific evaluation ns of dust combustion/deflagration/explosion hazards and mitigation actions in your facilities and operations.

Introduction

Why is this Presentation Important?

- Many modern industrial operations create dust as either a by-product or an end product.
- Some dusts can release hazardous amounts of energy when ignited.
- But, which dusts are susceptible? What can be done to reduce the risk of a dust explosion? Why do they occur?

Your Speaker: Chet Brandon

- VP of Ops & Corporate Safety Officer Occ Med & Safety Services provider, Regional Vice President, Region VII ASSP.
- EHS Professional (CSP & CHMM) with over 25 years of experience leading industrial organizations to EHS Excellence.
- Education: Safety Management (MS), I/O Psychology (MA) and Business Administration (BBA). Marshall University.
- Extensive experience in the process and manufacturing industries: Metals, Automotive, Aerospace, Glass, Electronic and Consulting.
- Expertise in high hazard processes such as explosive/combustible dust, PSM, complex automation, molten materials, high energy.
- Husband, Father, Pilot, Tinkerer.

The Hazard: Imperial Sugar


TIM'S

Introduction

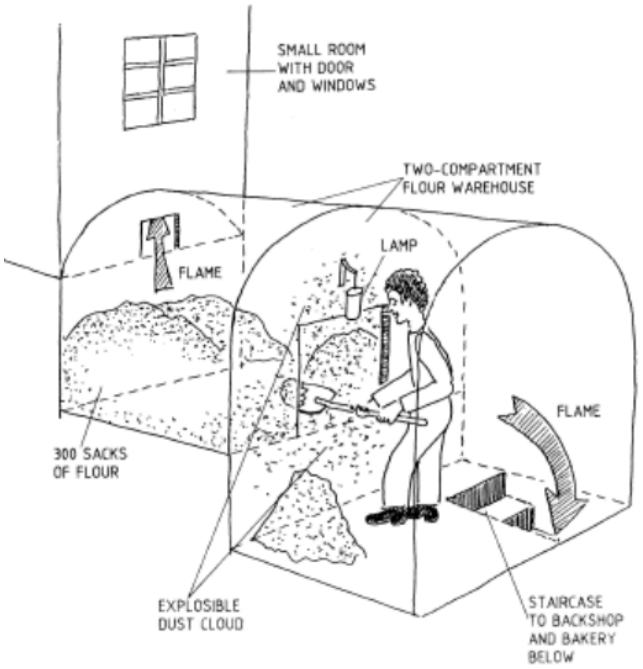
What this presentation will do for You:

- Introduce you to the knowledge of dust explosions enabling you to utilize (with support from knowledge experts) a systematic method of hazard assessment and mitigation providing maximum protection of the employees and assets.
- This training session will focus the application of explosive dust knowledge to your process.

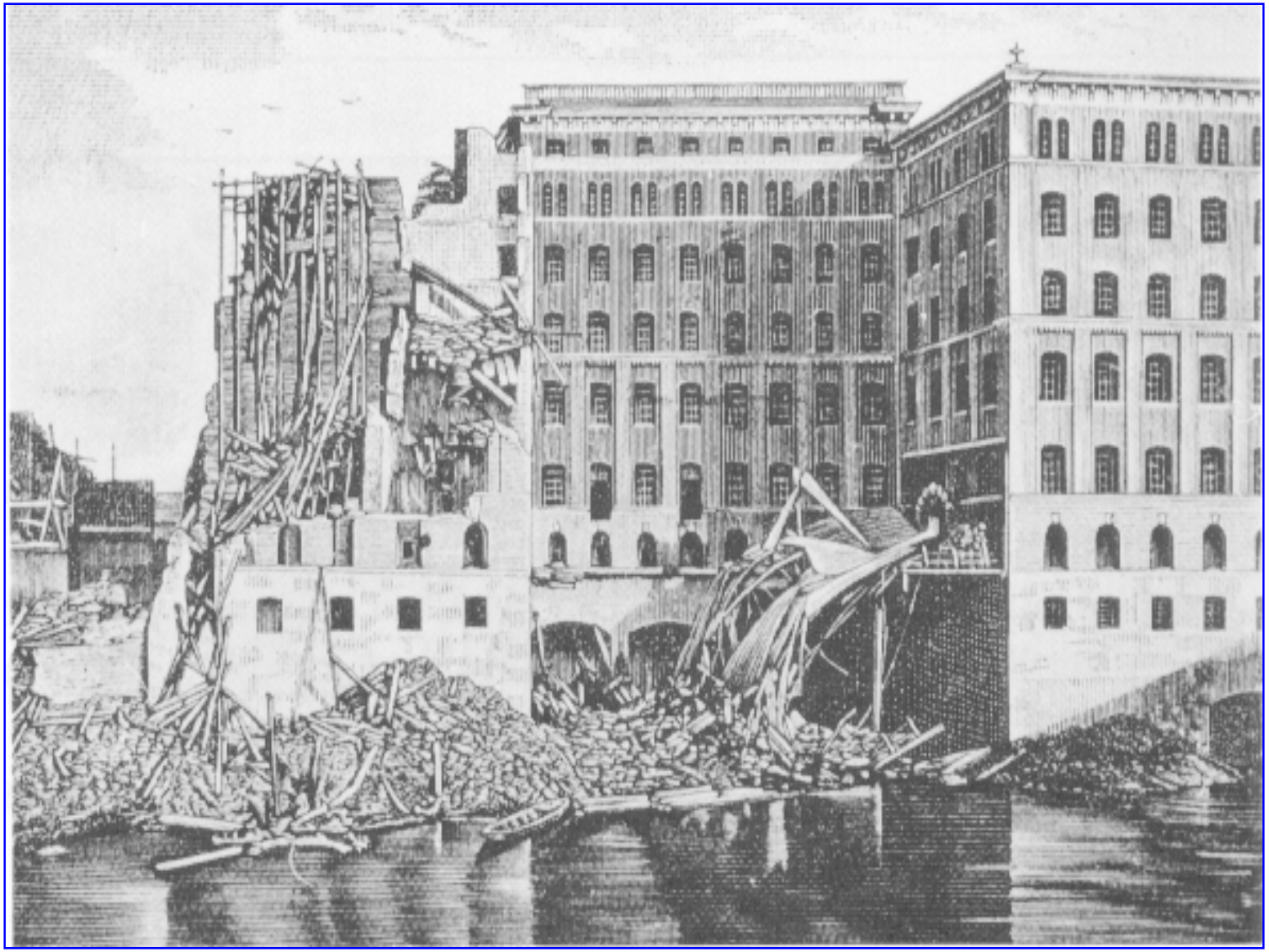
Brief History

- First recorded dust explosion occurred in Turin, Italy in 1785 (flour)

Artists Rendering of Activity Leading to the Dust Explosion in Turin



Source: Eckoff, Dust Explosions in the Process Industries.



Souce: Bartknecht, Dust Explosions, 1989.

Brief History

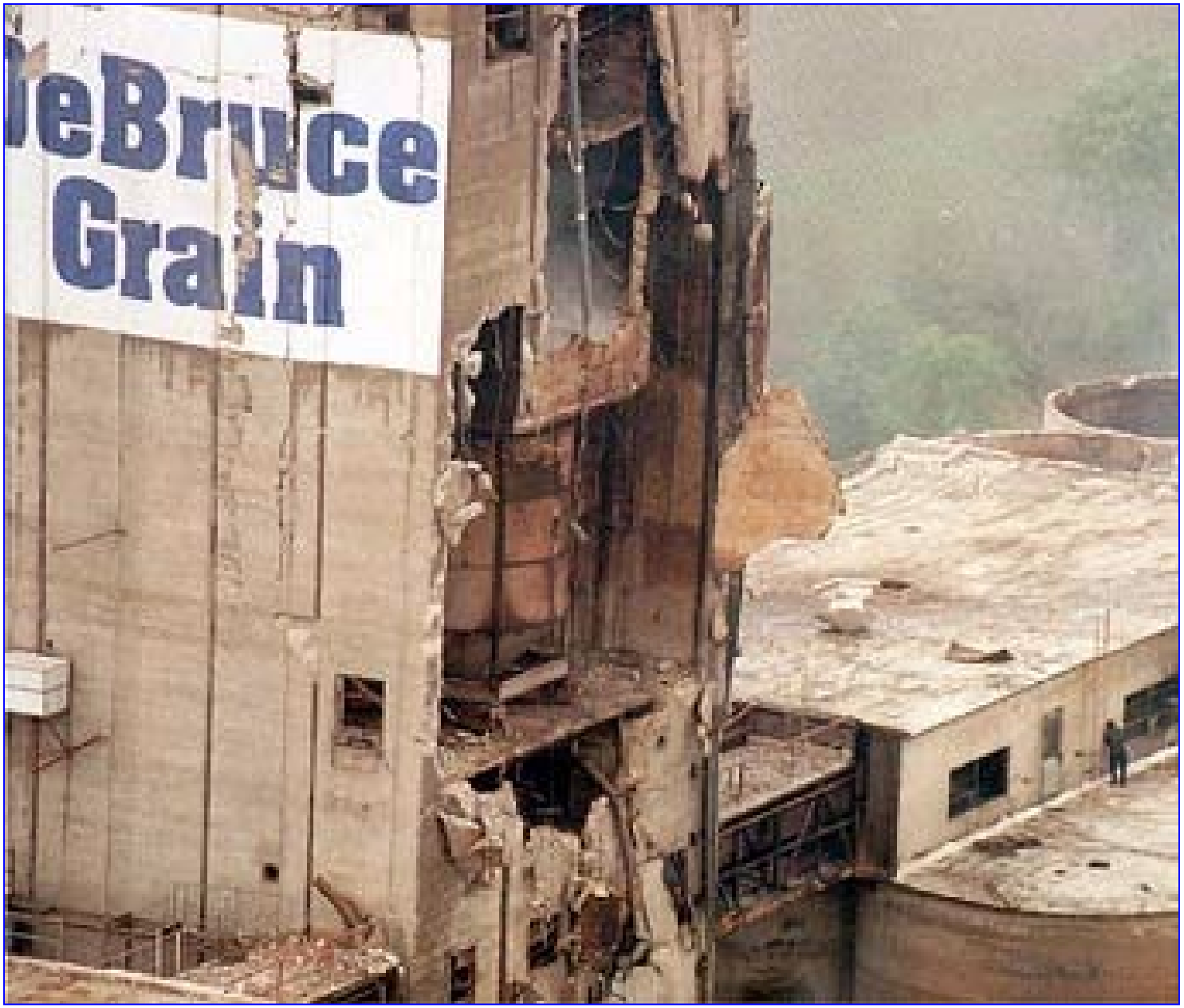
- Other incidents:
  - Stettin - Poland 1858 (grain)
  - Milwaukee - USA 1860 (flour)
  - Hameln - Germany 1887 (grain)
  - Monongah, WV 1907 (coal)

Source: MSHA Web Site, http://www.msha.gov/DISASTER/MONONGAH/MONON1.HTM, 2002.

Brief History

- Other incidents:
  - De Bruce, USA 1997 (wheat)

Source: Grose, Explosion of the DeBruce Grain Elevator, Grain Elevator Explosion Team, 1998.



Source: Grose, Explosion of the DeBruce Grain Elevator, Grain Elevator Explosion Team, 1998.

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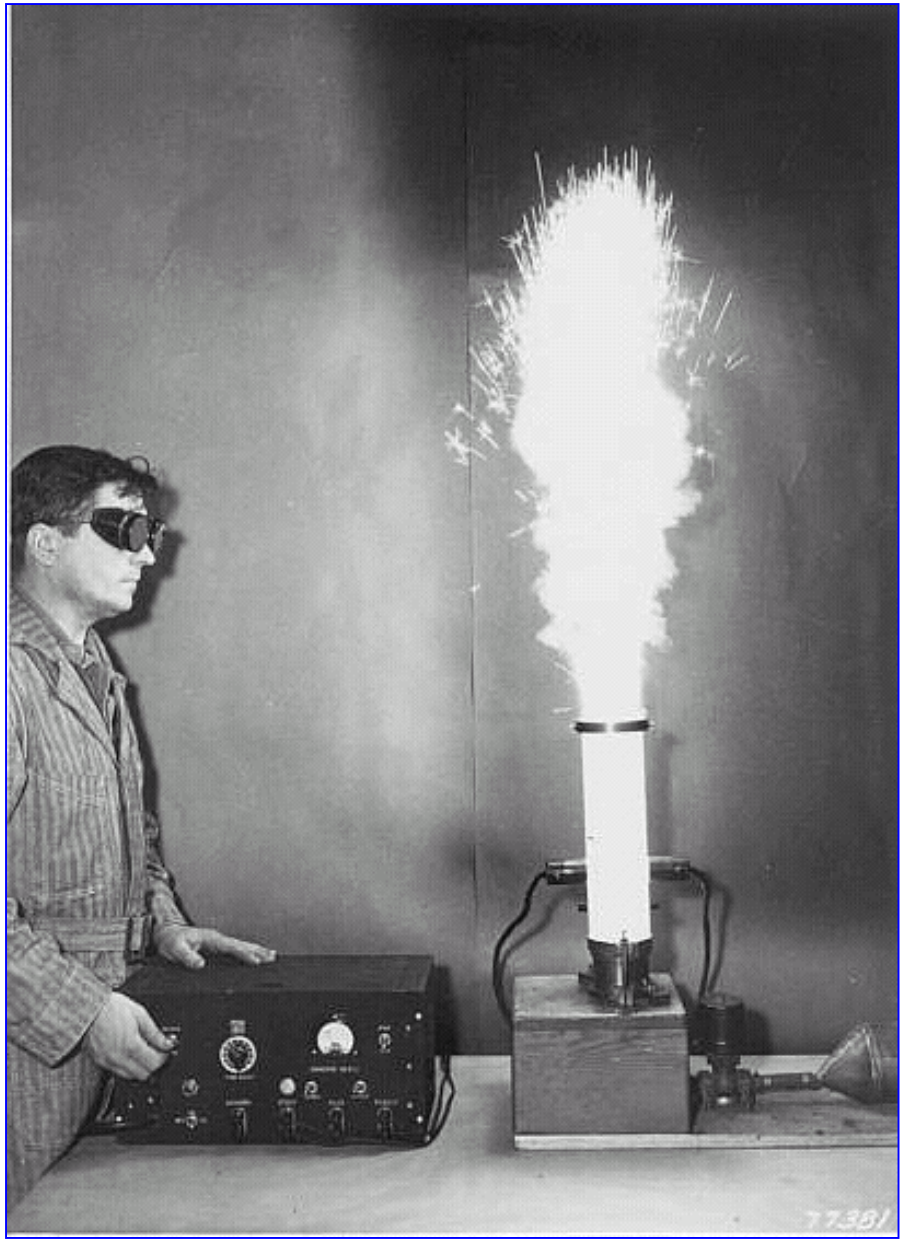
Government Involvement

- U.S. Geological Survey (late 1800s)
  - Monongah and Darr mining incidents left 600 dead (1907)
- Bureau of Mines… US Department of Interior (1910-1996)
  - Extensive dust explosion research (Hartmann)
- MSHA (1997 to Present)
- NIOSH
- CSB

Hartmann Apparatus



Source: U. S. Bureau of Mines Alumni Association, Online: http://www.bureauofmines.com/USBMAA.HTM, 2002.

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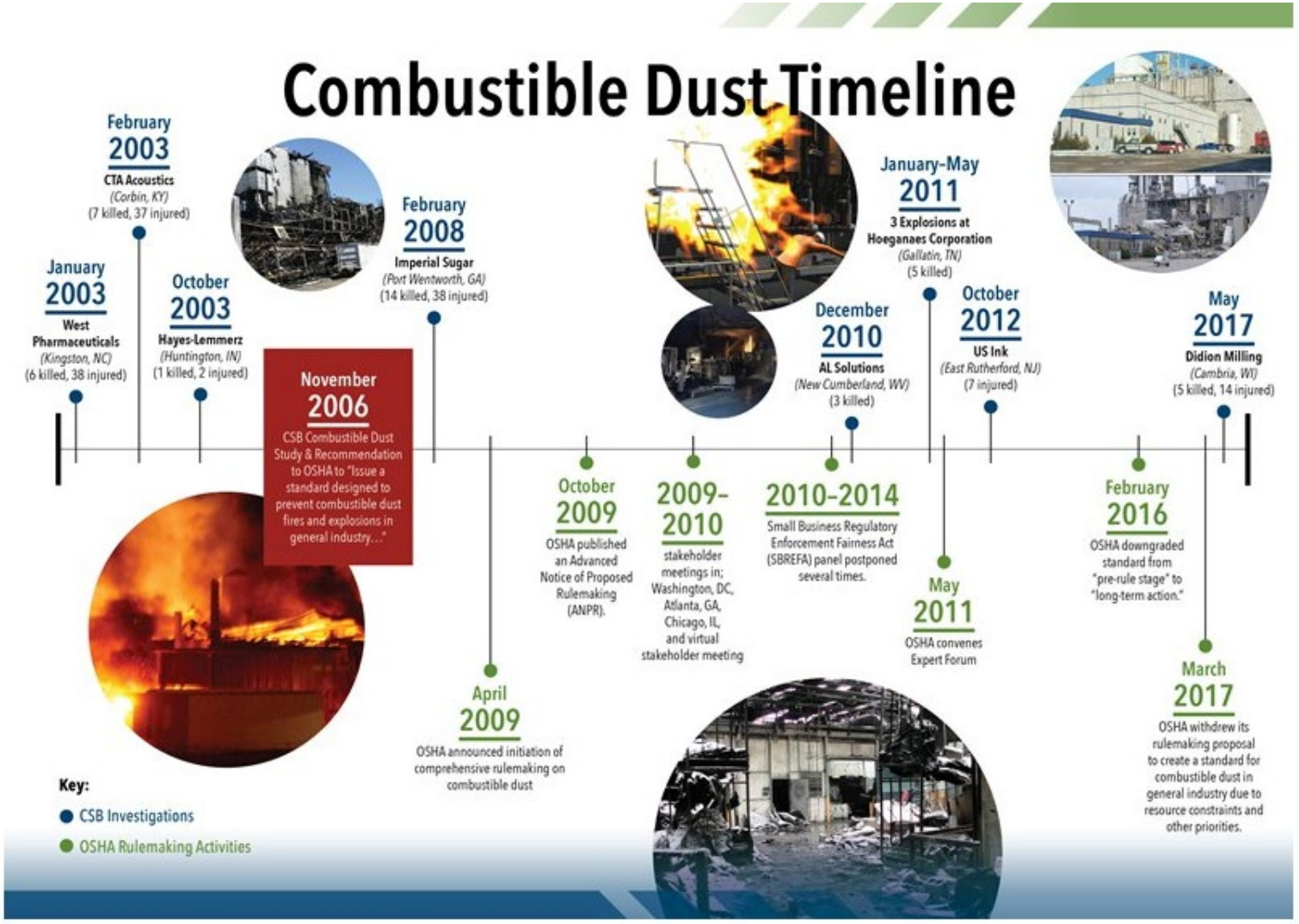
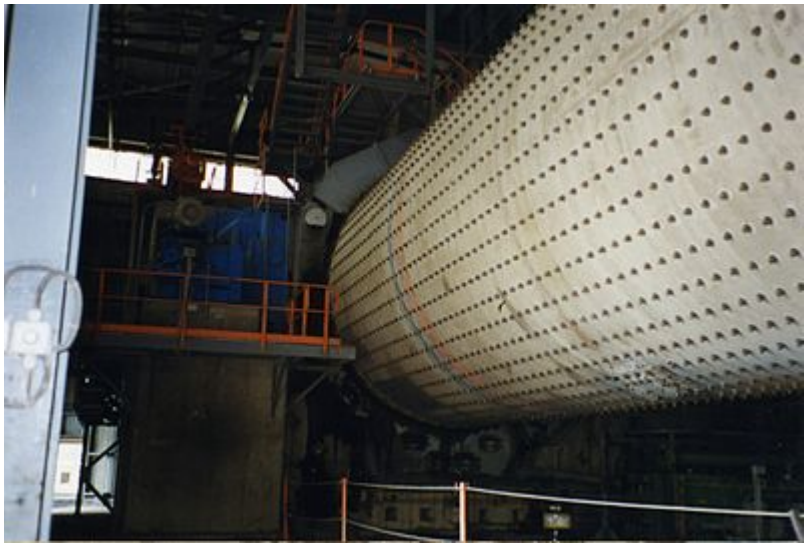
Recent History



Source: CSB.gov

Industries with combustible dusts

Include:



- Agriculture
- Food Products
- Chemicals
- Cement Processing
- Textiles
- Forest and furniture products
- Metal processing
- Tire and rubber manufacturing plants
- Paper products
- Pharmaceuticals
- Wastewater treatment
- Recycling operations (metal, paper, and plastic)
- Coal dust in coal handling and processing facilities

Anatomy of a Dust Explosion

- Understanding dust reactions
- Dust reaction demonstration
- Secondary explosions
- Identification of explosive dusts

Source: Fike Corporation, Fike Explosion Protection Solutions, 1999.

Understanding Dust Reactions

Prerequisites:

- Finely divided solids that pass through a No. 40 USA Standard sieve or less that 425 micron
- Five Parameters for a reaction
- A dust capable of propagating a burning reaction

Types of Reactions

- Smoldering
- Deflagration
- Explosion

Understanding Dust Reactions

Material Size

- Finely divided materials have a high total contact surface area with oxygen in the atmosphere
- The large surface area of finely divided materials allows rapid oxidation to occur
- The relatively low mass particles are more easily suspended in air

Understanding Particle Size

STANDARD MESHOPENING PARTICLE

Tyler	U.S.	mm	inches
4	4	4.75	0.187
6	6	3.35	0.132
8	8	2.36	0.094
10	12	1.70	0.066
12	14	1.40	0.056
14	16	1.18	0.047
16	18	1.00	0.039
20	20	0.85	0.033
24	25	0.71	0.028
28	30	0.60	0.023
32	35	0.50	0.020
35	40	0.425	0.017
42	45	0.355	0.014
48	50	0.300	0.012
60	60	0.250	0.0098
65	70	0.212	0.0083
80	80	0.180	0.0070
100	100	0.150	0.0059
115	120	0.125	0.0049
150	140	0.106	0.0041
170	170	0.090	0.0035
200	200	0.075	0.0029
250	230	0.063	0.0025
270	270	0.053	0.0021
325	325	0.045	0.0017
400	400	0.038	0.0015
—	500	0.025	0.0010

74 mircons = 200 Mesh (very fine sand)

10 microns = <635 Mesh (face powder)

Understanding Dust Reactions

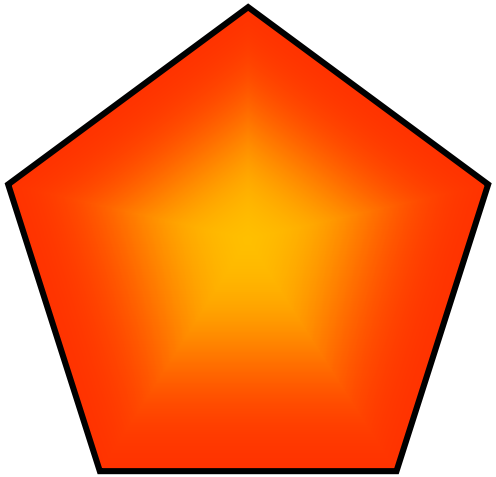
Reactive Dusts

- Dusts which react exothermically with air
- Exothermic reaction: *fuel + oxygen* $\Rightarrow$ *oxides + heat*
- Typical reactive dusts:
  - Natural organic materials
  - Synthetic organic materials
  - Coal and Peat
  - Metals

Understanding Dust Reactions

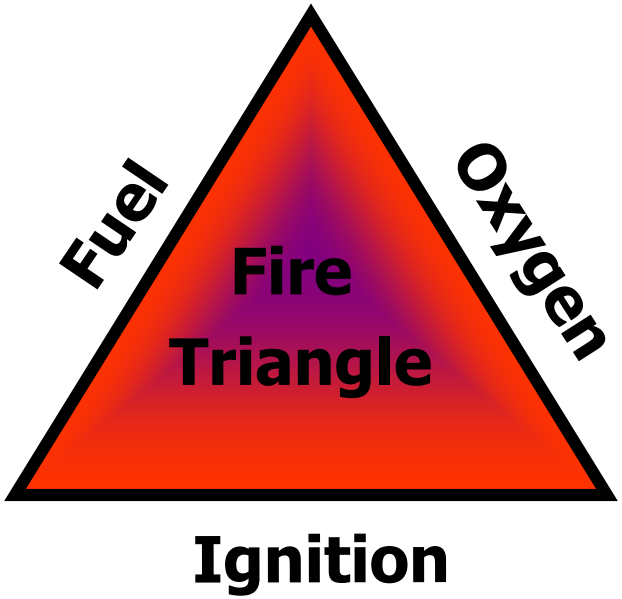
Five Parameters of Dust Explosions

- Dust Concentration (Fuel)
- Ignition Source (Energy)
- Atmosphere (Oxygen)
- Confinement
- Suspension

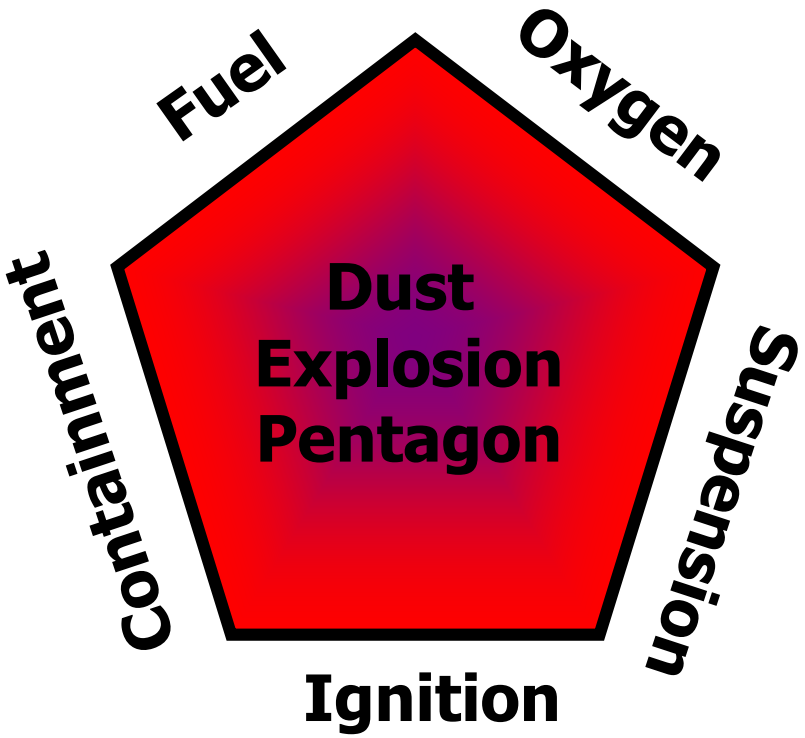


Understanding Dust Reactions

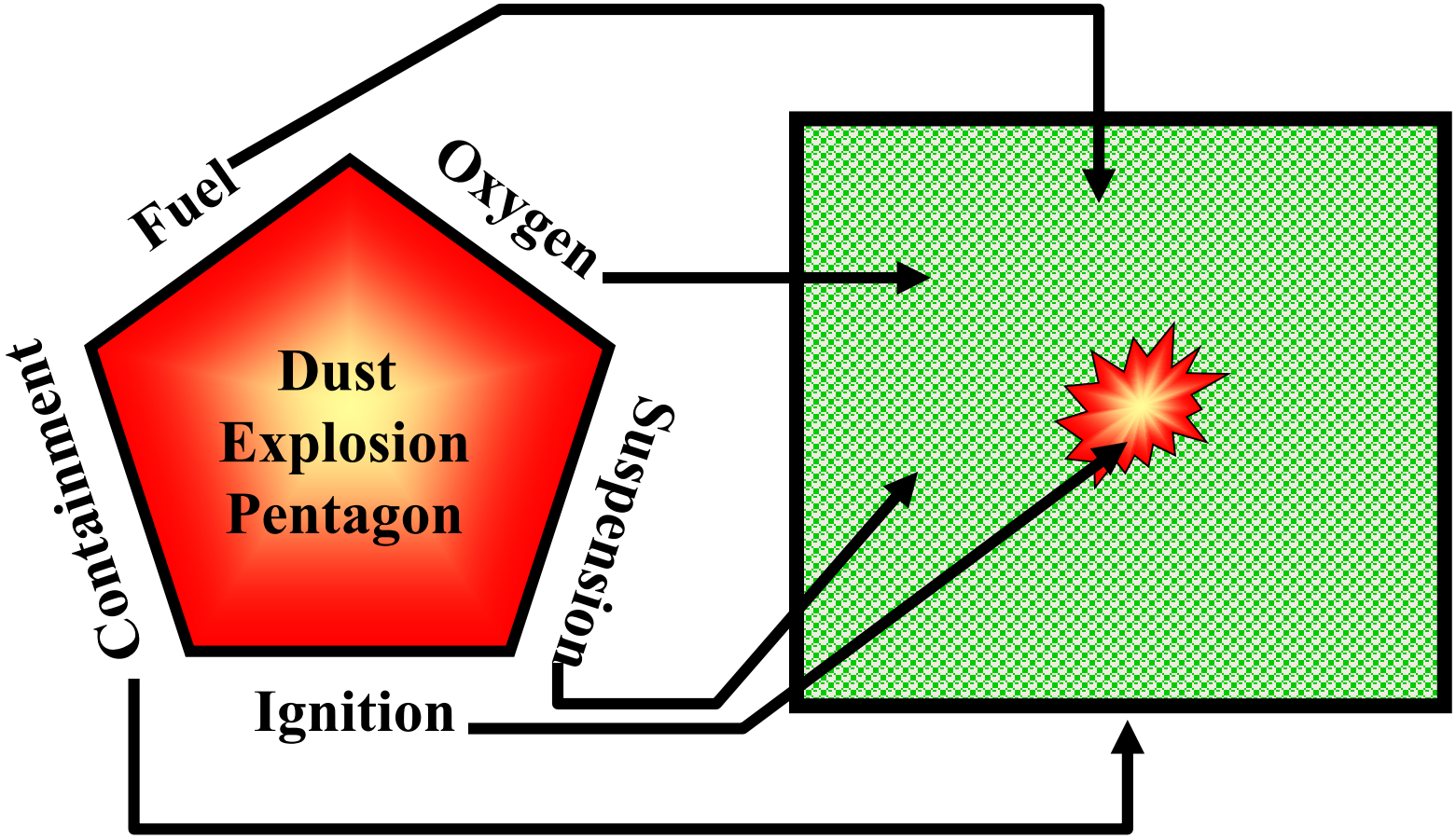
From the Fire Triangle



To the Dust Explosion Pentagon



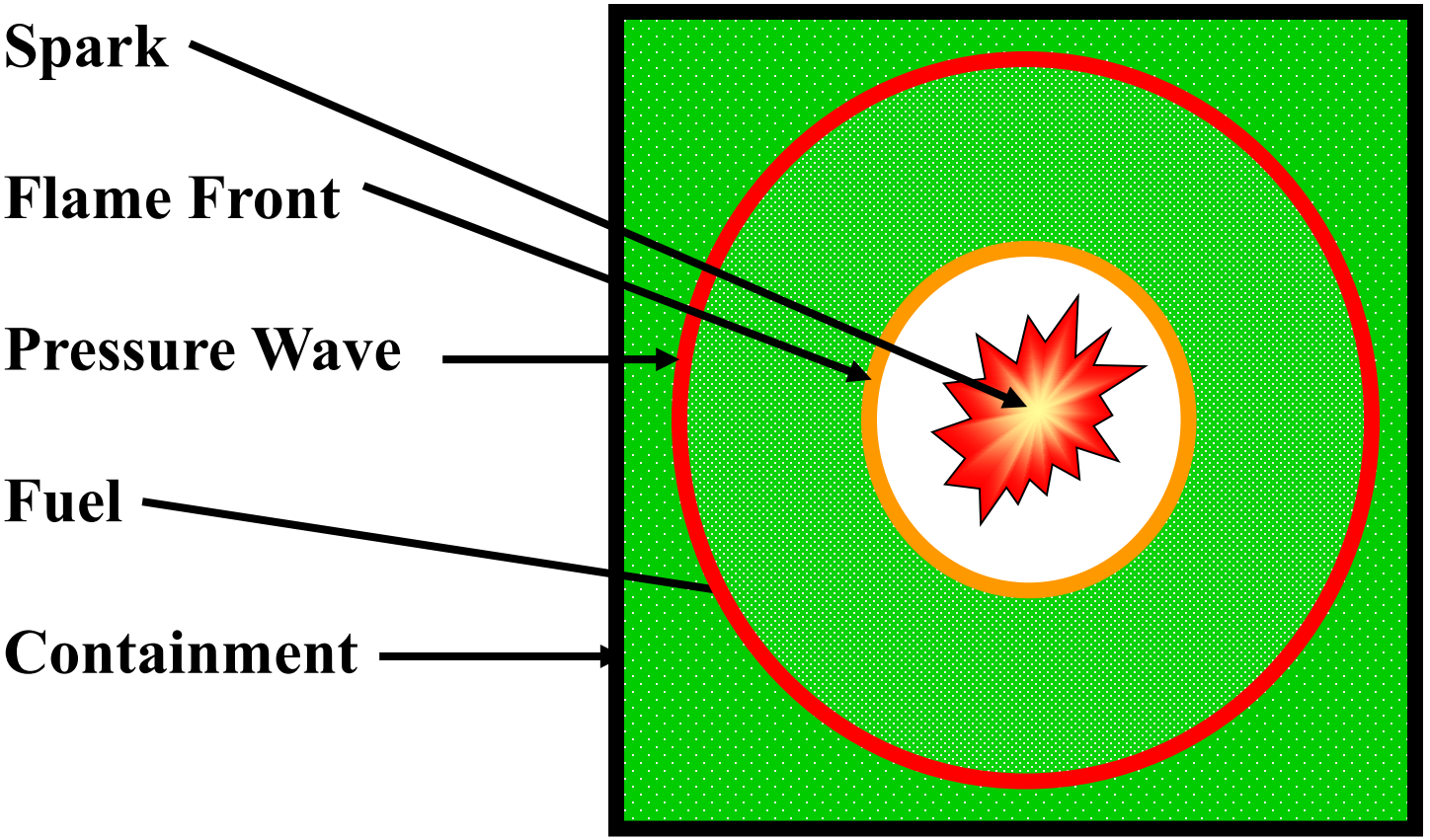
Dust Explosion Parameters



Explosion Anatomy

- All five parameters are met
- Point of Ignition
- Flame Front
- Pressure Wave of Cool Compressed Gas
- High pressure generated in containing vessel

Dust Explosion Mechanism



Pressure Wave Demonstration

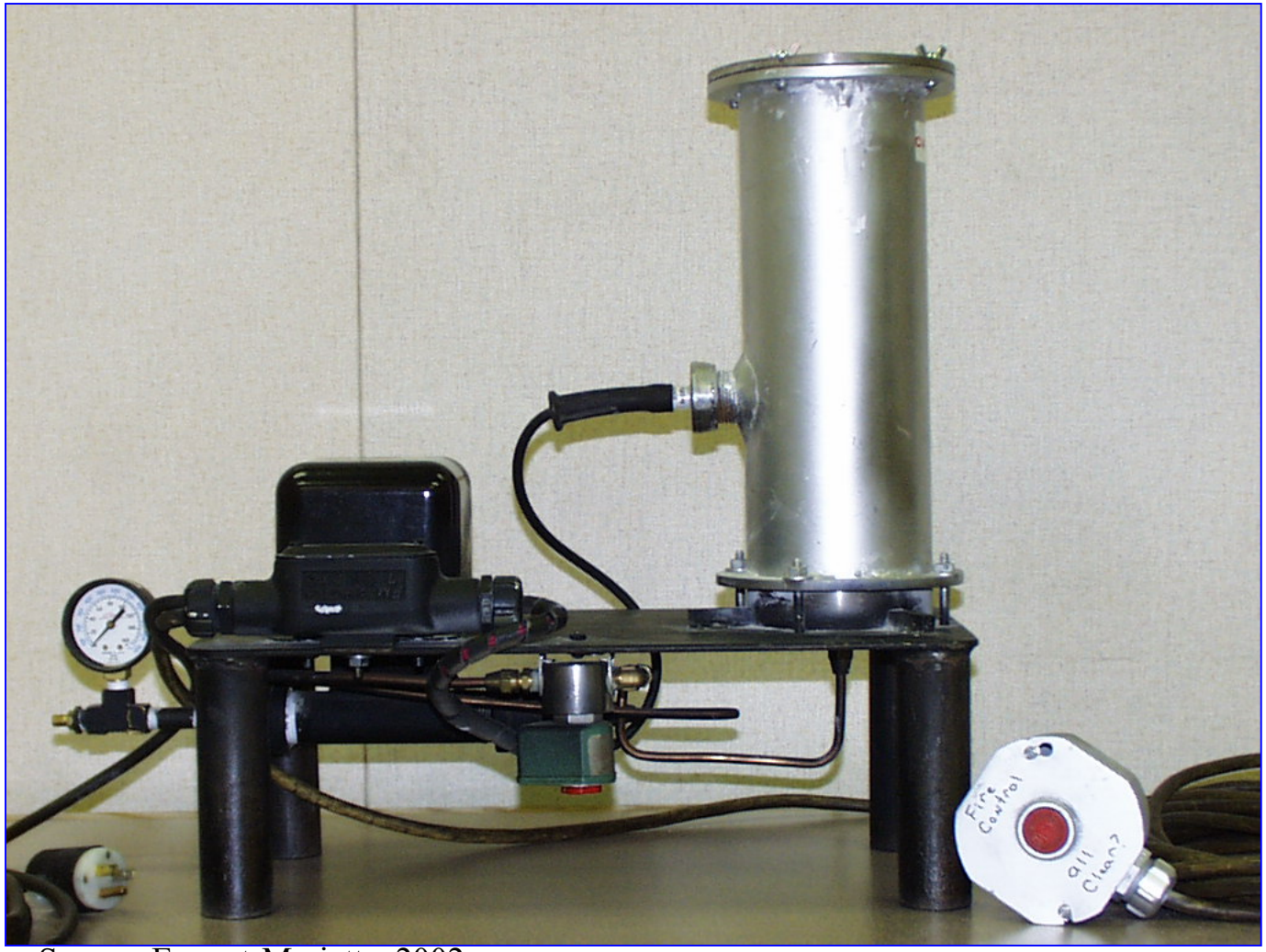
Source: Discovery Channel, World of Wonder Segment: Dust Explosions, 1998.

Dust Deflagration Demonstration

- 1.2 litre Hartmann Apparatus
- Small scale reaction of finely divided flour
- Demonstrates the 5 key parameters of dust reactions

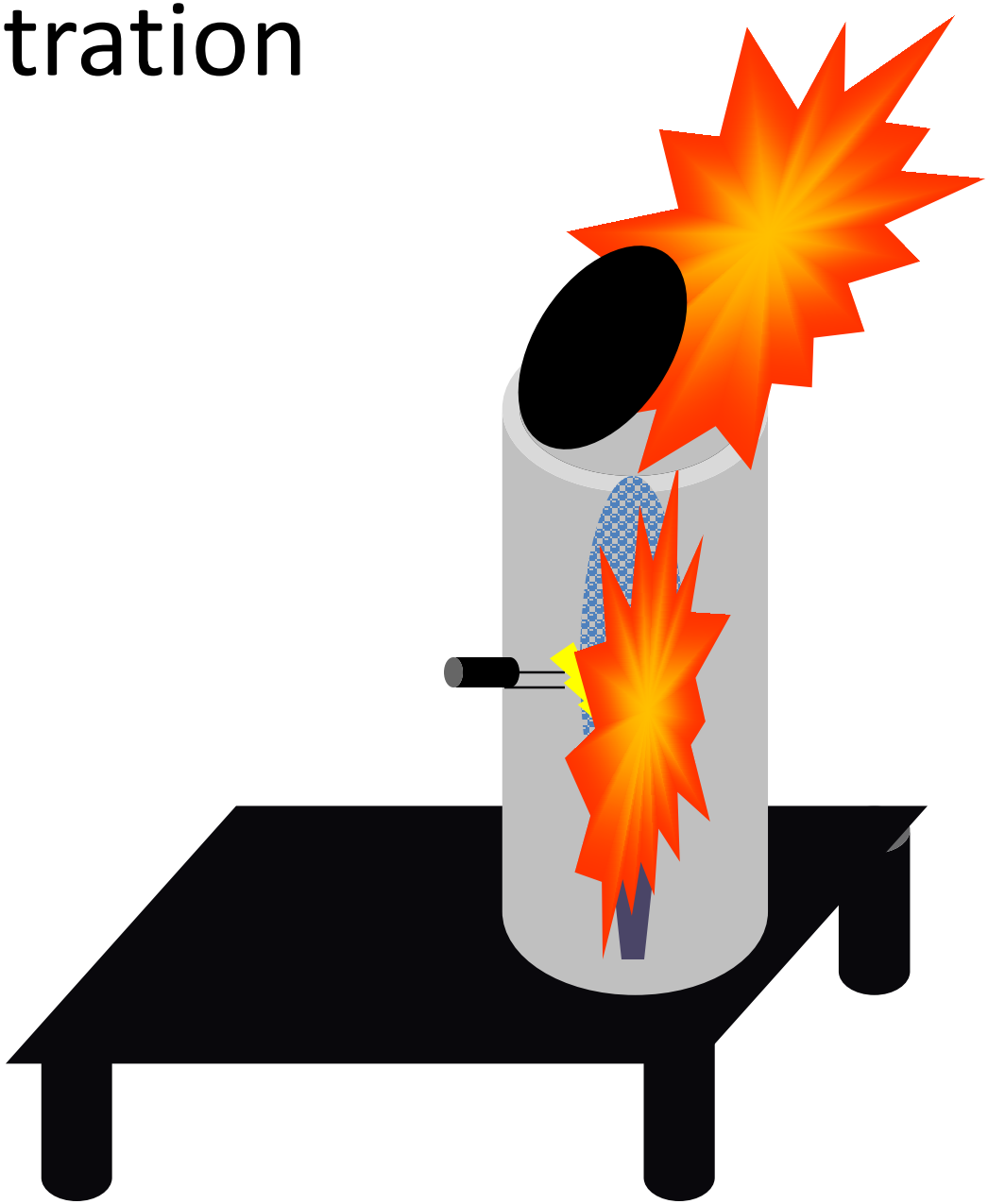
Source: U. S. Bureau of Mines Alumni Association, Online: http://www.bureauofmines.com/USBMAA.HTM, 2002

1.2 L Hartmann Bomb



Source: Eramet-Marietta, 2002.

Demonstration



RCB

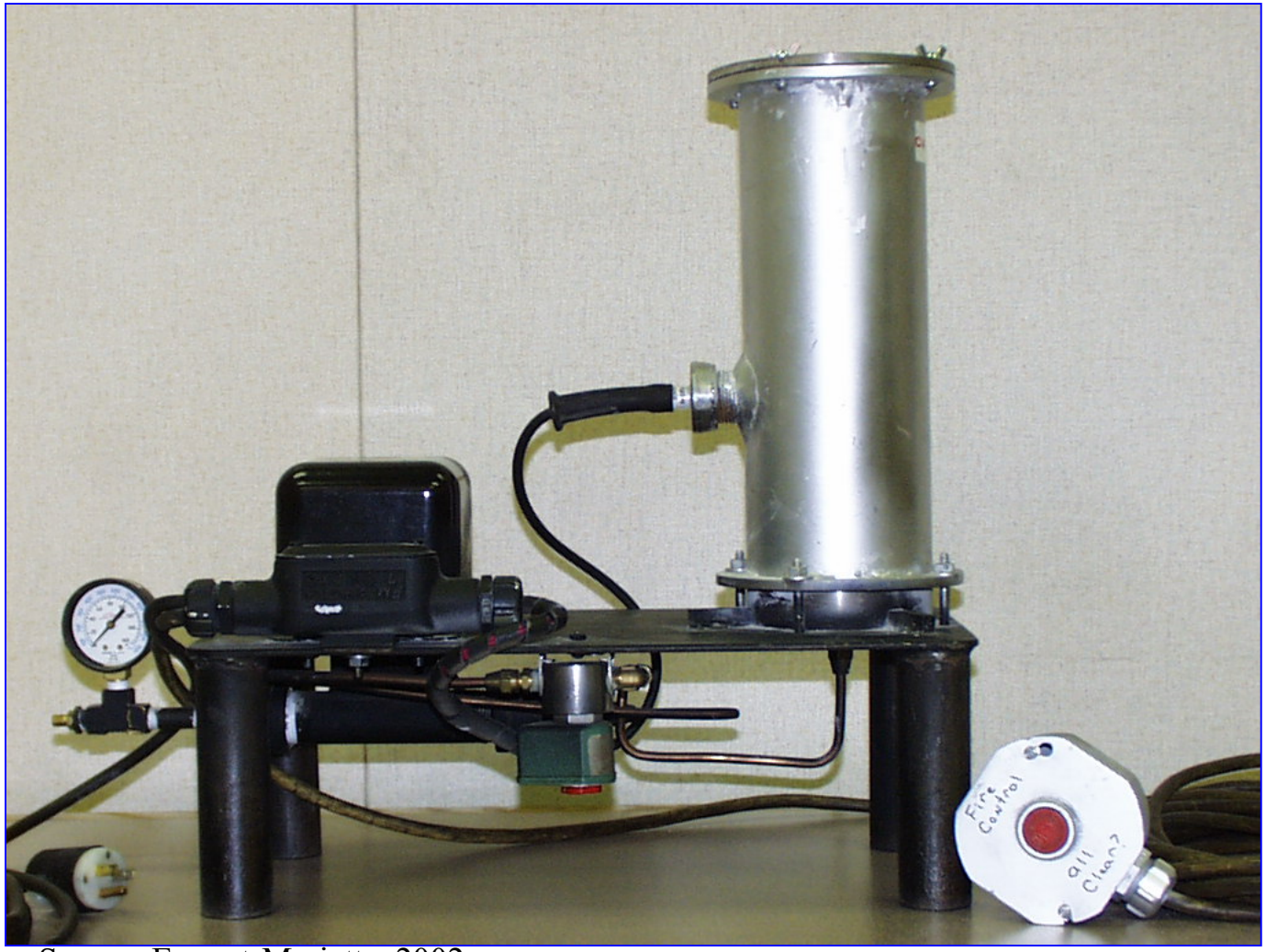
Identification of Explosive dusts

- *Fuel + oxygen = oxides + energy*
- Must rapidly oxidize
- Typical reactive dusts:
  - Natural organic materials
  - Synthetic organic materials
  - Coal and Peat
  - Metals
- If you are unsure….
  - Reference materials
  - GET IT TESTED

Testing Apparatus

- 1.2 liter Hartmann test apparatus
- Siwek 20 liter sphere - ASTM Standard of today

1.2 L Hartmann



Source: Eramet-Marietta, 2002.

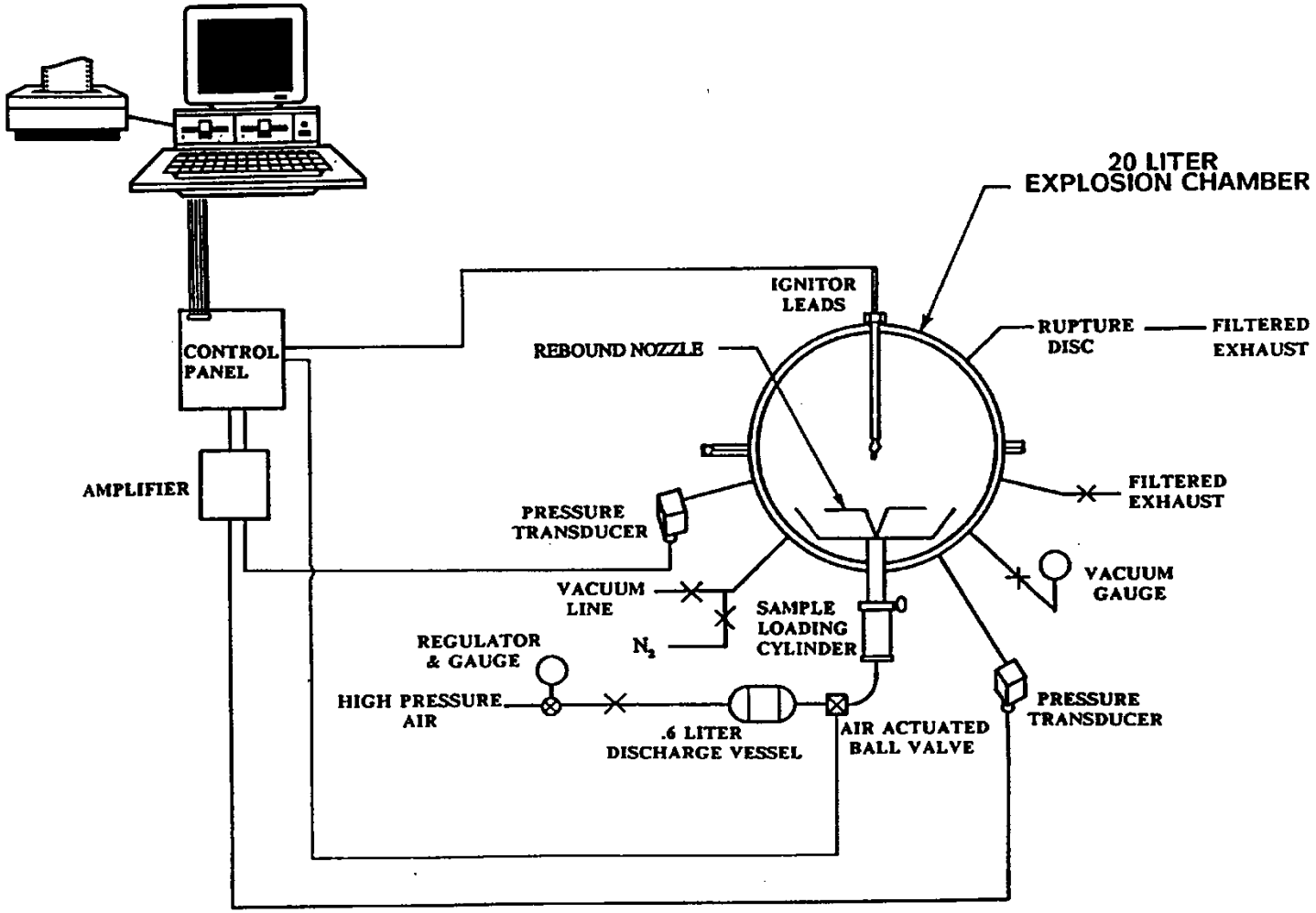
Fike 20 L Sphere

Source: Fike Corporation, Fike Explosion Protection Solutions, 1999.

Fike 10 m^3 Sphere

Source: Fike Corporation, Fike Explosion Protection Solutions, 1999.

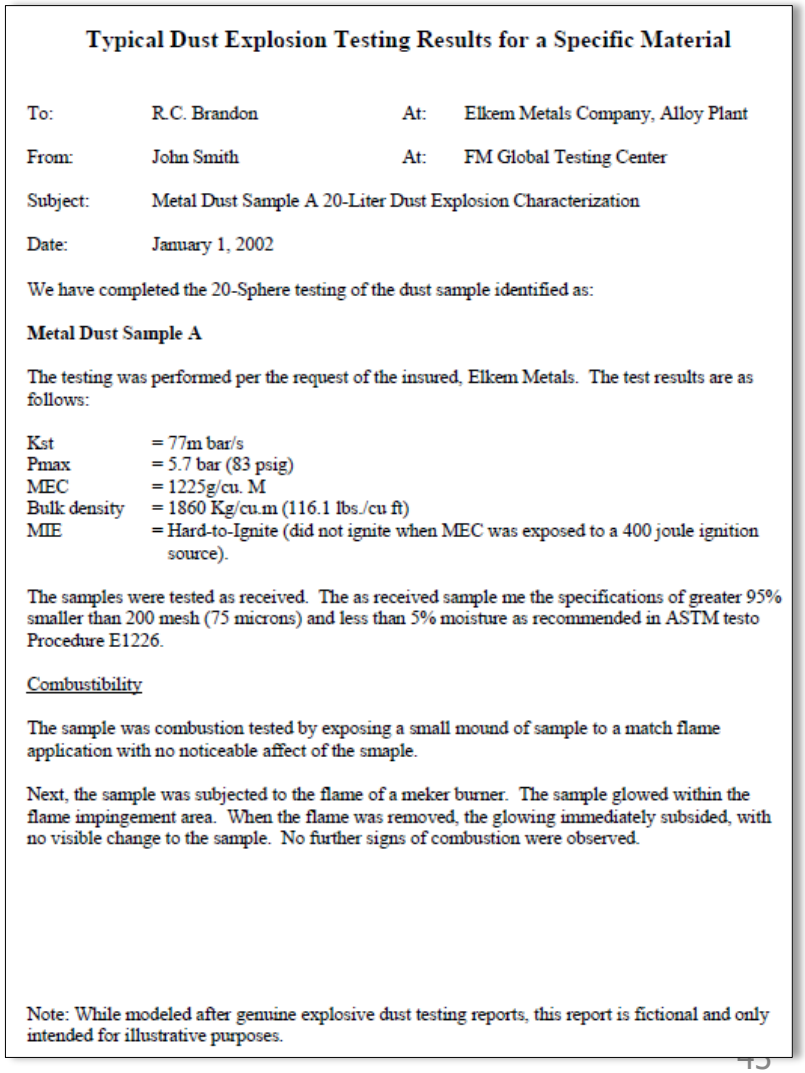
Fike 20 l Sphere Instrumentation



Source: Fike Corporation, Fike Explosion Protection Solutions, 1999.

Example Dust Explosion Testing Report

- Creditable lab
- Use of an ASTM Method (e.g. ASTM Std E1226)
- Method description
- Results



Typical Dust Explosion Testing Results for a Specific Material

To: R.C. Brandon At: Elkem Metals Company, Alloy Plant

From: John Smith At: FM Global Testing Center

Subject: Metal Dust Sample A 20-Liter Dust Explosion Characterization

Date: January 1, 2002

We have completed the 20-Sphere testing of the dust sample identified as:

Metal Dust Sample A

The testing was performed per the request of the insured, Elkem Metals. The test results are as follows:

Kst = 77m bar/s
Pmax = 5.7 bar (83 psig)
MEC = 1225g/cu. M
Bulk density = 1860 Kg/cu.m (116.1 lbs./cu ft)
MIE = Hard-to-Ignite (did not ignite when MEC was exposed to a 400 joule ignition source).

The samples were tested as received. The as received sample me the specifications of greater 95% smaller than 200 mesh (75 microns) and less than 5% moisture as recommended in ASTM testo Procedure E1226.

Combustibility

The sample was combustion tested by exposing a small mound of sample to a match flame application with no noticeable affect of the smaple.

Next, the sample was subjected to the flame of a meker burner. The sample glowed within the flame impingement area. When the flame was removed, the glowing immediately subsided, with no visible change to the sample. No further signs of combustion were observed.

Note: While modeled after genuine explosive dust testing reports, this report is fictional and only intended for illustrative purposes.

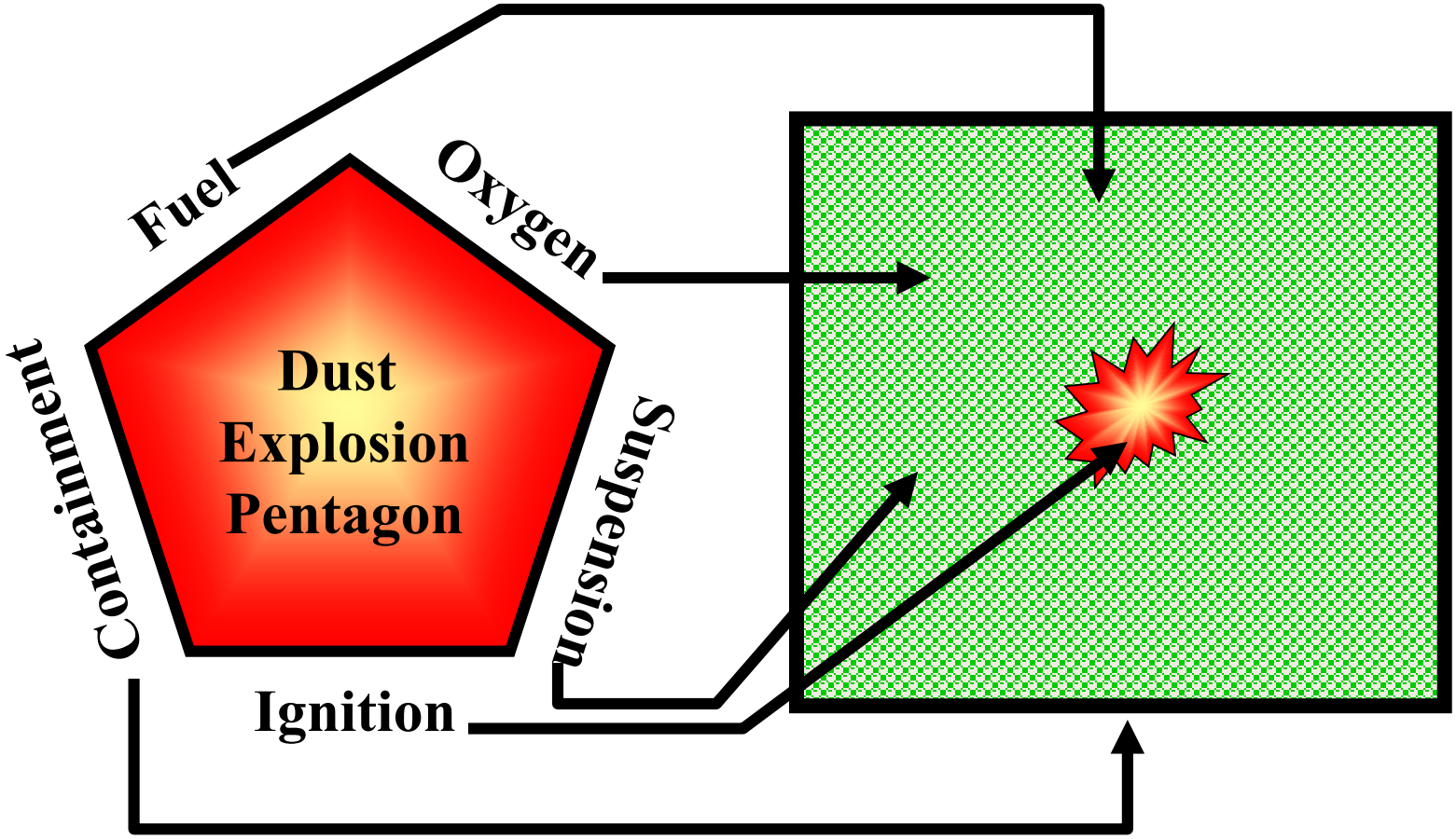
Fuel Parameters

- Size
- Concentration (MEC)
- Purity
- Turbulence
- Get YOUR our material tested
- Don’t used information from books for your design parameters

Prevention of a Dust Explosion

- Use of the pentagon to help prevent dust explosions
- Engineering out the dust explosion hazard

Dust Explosion Parameters



Prevention of a Dust Explosion

- Use of the pentagon to help prevent dust explosions
- Engineering out the dust explosion hazard
  - dust explosivity results
  - equipment
  - quality control system
  - housekeeping

Elimination of Dust Explosion Parameters

- Eliminate one or more of the 5 parameters
  - Fuel – Reduce concentration below MEC
  - Oxygen – Use inerting agents
  - Energy – Control ignition sources
  - Suspension – Control suspension of dust in air
  - Containment – Design vessels for explosions

Generation of Design Data For Explosion Protection

- Data generated in the 20 L sphere is recognized as more accurate than those from the Hartmann test apparatus
- ASTM Standard E1226 Data generated using ASTM methods employs precise standards for preparation and testing of samples that include concentrations, size, and ignition energy

Generation of Design Data For Explosion Protection

Importance of Testing Specific Materials

- It is essential to use data generated for specific products
- Use of explosion data from what are believed to be *similar* dusts to those in question is <u>not recommended</u>

Generation of Design Data For Explosion Protection

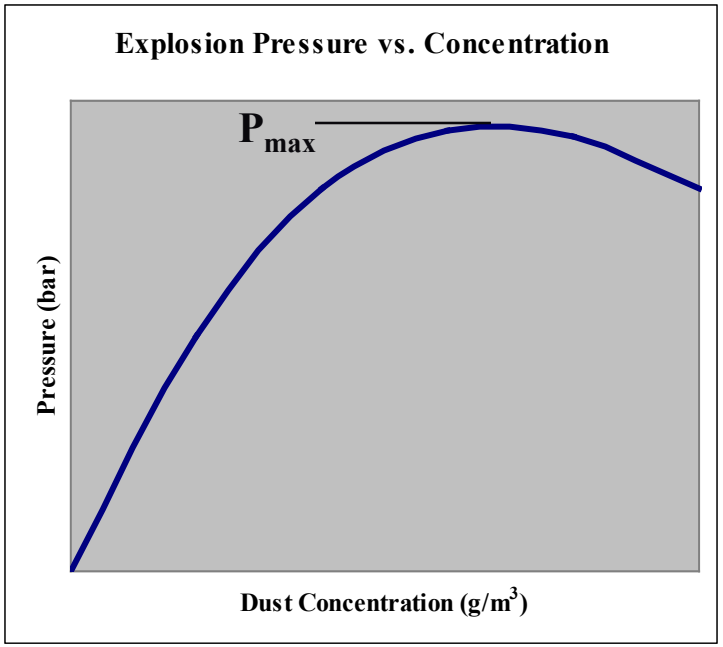
Tests using scientifically valid procedures quantifies 6 key explosion characteristics for your dust:

- **Maximum Pressure Developed**
- **Maximum Rate of Pressure Rise**
- **Deflagration Index**
- **Minimum Ignition Energy**
- **Minimum Explosive Concentration**
- **Maximum Limiting Oxygen Concentration**

Maximum Pressure Developed

- Greatest pressure generated
- Measured in bars
- Determines max pressure exposure to a containing vessel
- Predicts likelihood of vessel failure

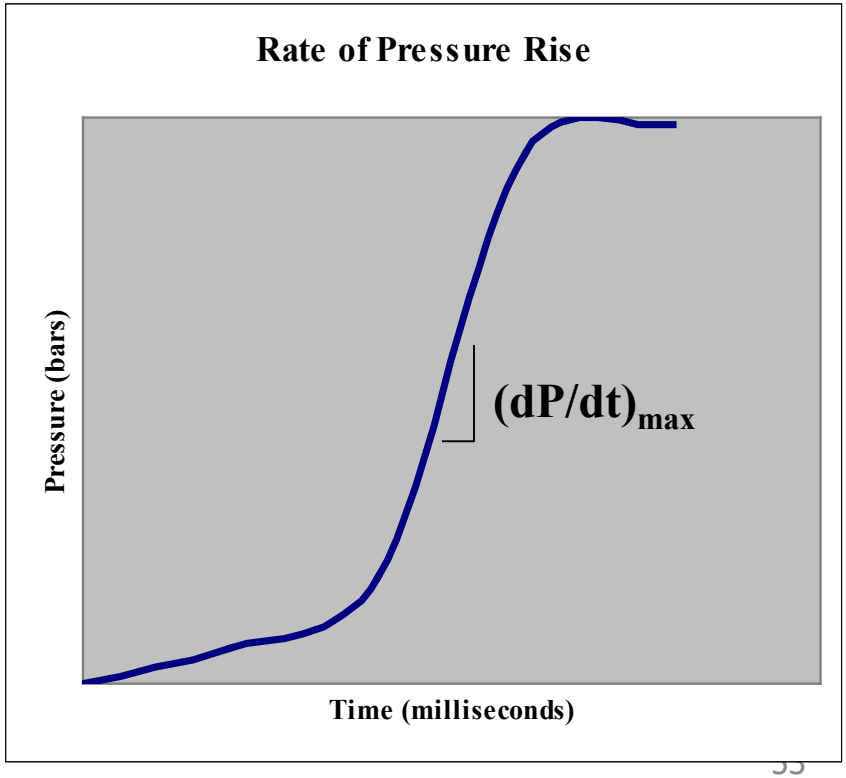
P_{max}



Maximum Rate of Pressure Rise

- The rate of pressure increase over time at the steepest part of the pressure-versus-time curve
- Measured in bar/s
- Used to determine necessary venting capacity of closed vessels

$(dP/dt)_{max}$



Deflagration Index

- The maximum dP/dt normalized to a 1.0 m^3 volume
- Measured bar-meters/second
- Allows a comparison of data from different sized test vessels

K_{st}

$$K_{st} = V^{1/3} (dP/dt)_{max}$$

Minimum Ignition Energy

MIE

- The minimum amount of energy released in a cloud of suspended dust causing indefinite flame propagation
- Measured in millijoules
- Determines what energy sources must be controlled to prevent ignition of a dust cloud

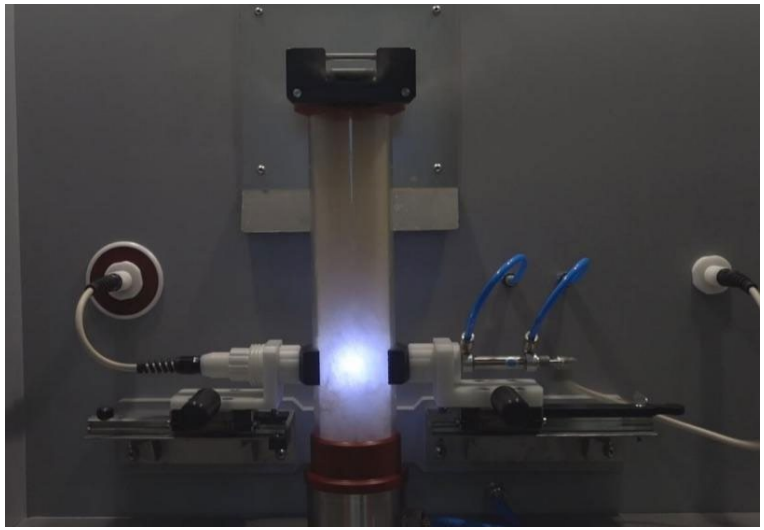
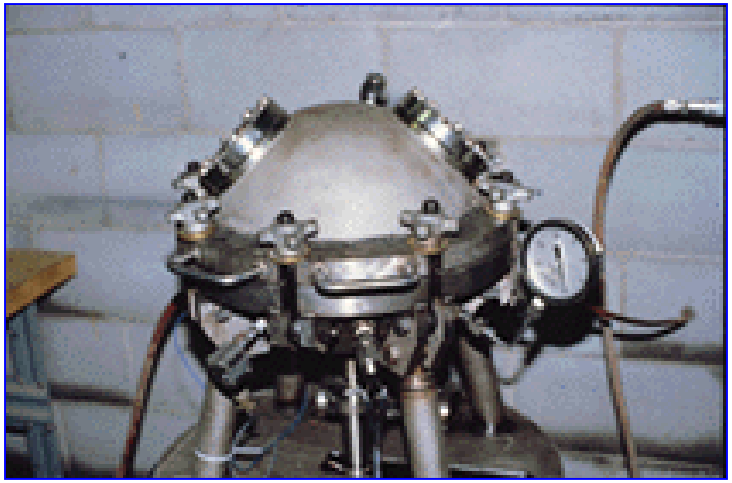


Photo Source: ANKO

Minimum Explosive Concentration

- The lowest concentration of a dust that can support a self-propagating reaction
- Measured mg/m^3
- Used in designing and operating explosive dust systems below the level of suspended fuel required for combustion

MEC

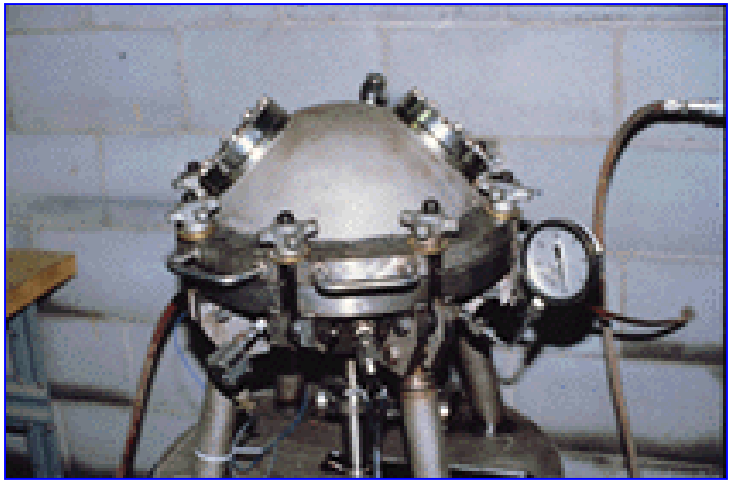


Source: Fike Corporation,
Fike Explosion Protection Solutions, 1999.

Maximum Oxygen Level

$O_{2\ max}$

- The level of oxygen at or below which a dust is not capable of sustaining reaction
- Reported as a percentage of oxygen in a given volume
- Used in designing inerted atmospheres for systems processing reactive dusts



Source: Fike Corporation,
Fike Explosion Protection Solutions, 1999.

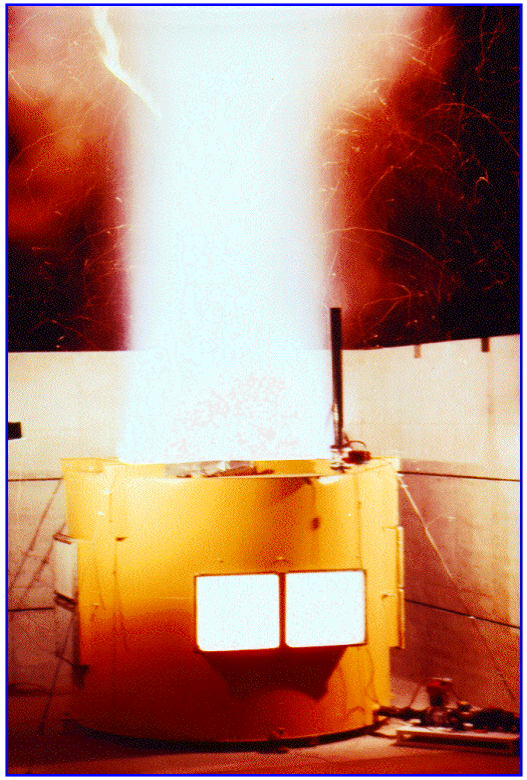
Engineering Out the Hazard

- Assume an explosion will occur
- Select proper equipment for use with explosive dusts
- Follow existing design standards
- Include safe maintenance capability in system design
- Utilize explosion protection systems

Engineering Out the Hazard

Types of Explosion Protection Systems

- Isolation
- Venting
- Suppresion
- Containment



Source: Fike Corporation, Fike Explosion Protection Solutions, 1999.

Engineering Out the Hazard

Isolation

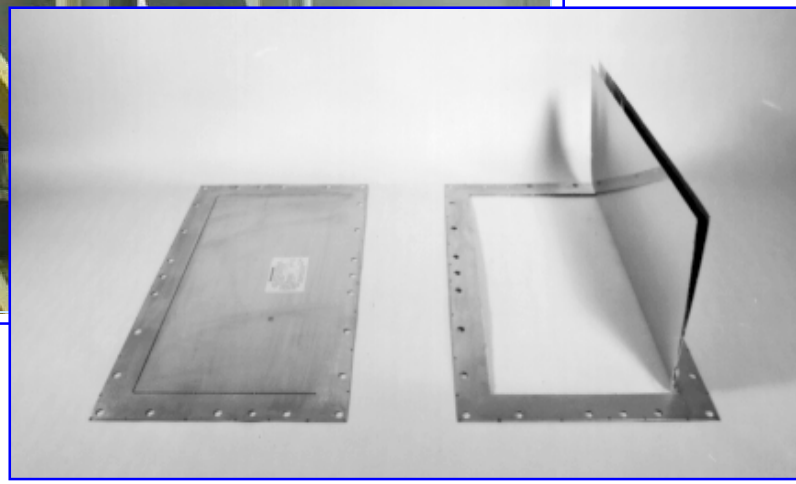
Mechanical

Chemical

Source: Fike Corporation, Fike Explosion Protection Solutions, 1999.

Engineering Out the Hazard

Venting



Source: Fike Corporation, Fike Explosion Protection Solutions, 1999.

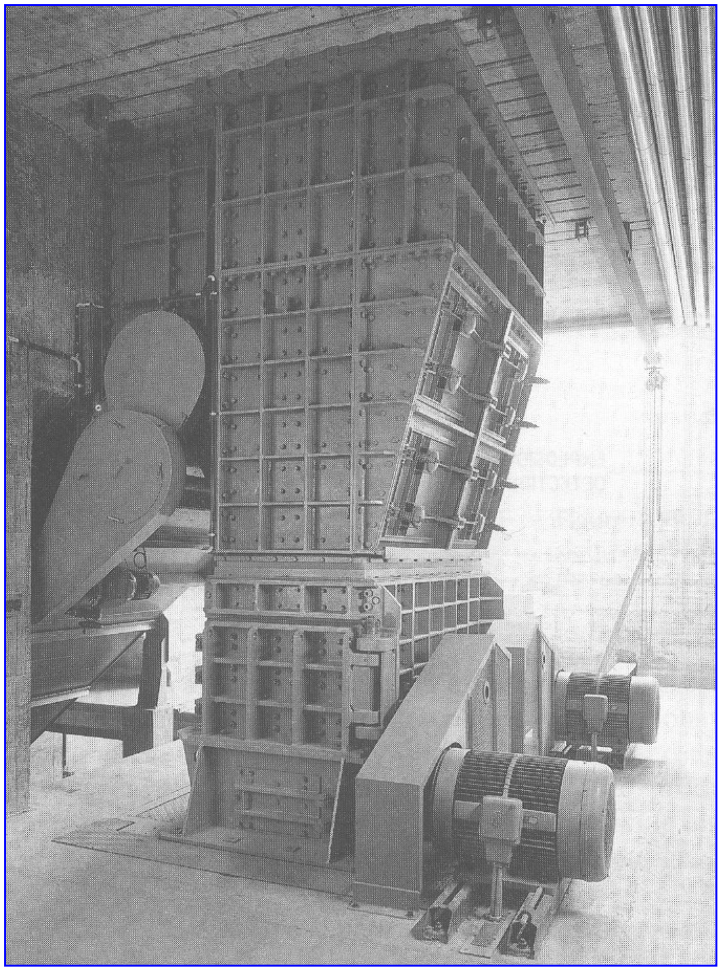
Engineering Out the Hazard

Suppression

Source: Fike Corporation, Fike Explosion Protection Solutions, 1999.

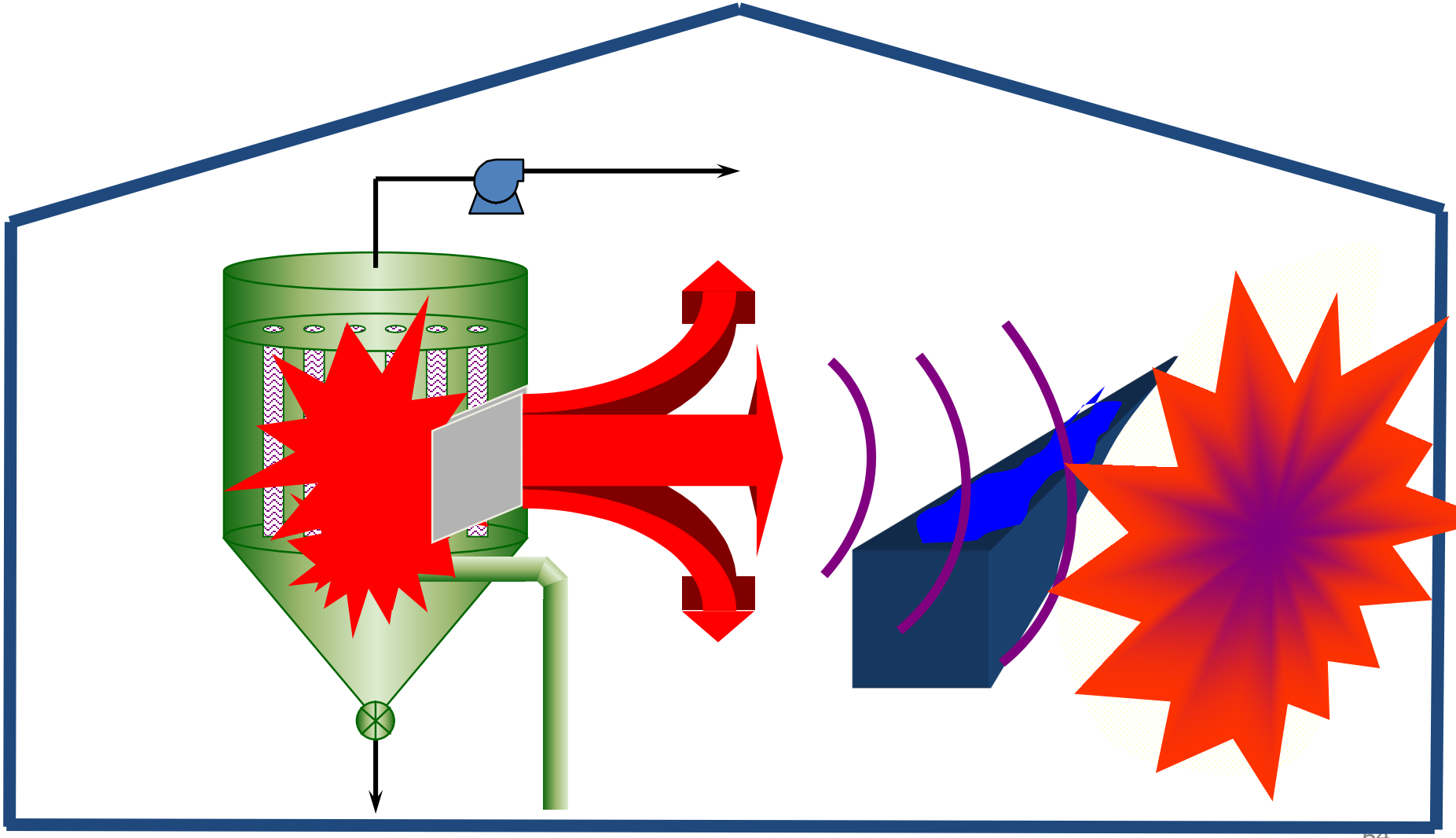
Engineering Out the Hazard

Containment



Source: Eckhoff, Dust Explosions in the Process Industries, 2nd Ed, 1997.

Secondary Explosion Mechanism



Secondary Explosion Fuel

Source: Building-Products.com, *Be on the Lookout for Combustible Dust Hazards*, 12/27/2018

Secondary Explosions

- Can create the greatest injury and damage
- Associated with dust accumulated on the horizontal surfaces
- Occur when dust becomes suspended by the pressure wave and is ignited by the flame front of the primary explosion

Source: Elkem Metals Co., LP, 2002.

Secondary Explosions

Source: Elkem Metals Co., LP, 2002.

Secondary Explosions

Source: Elkem Metals Co., LP, 2002.

Secondary Explosions

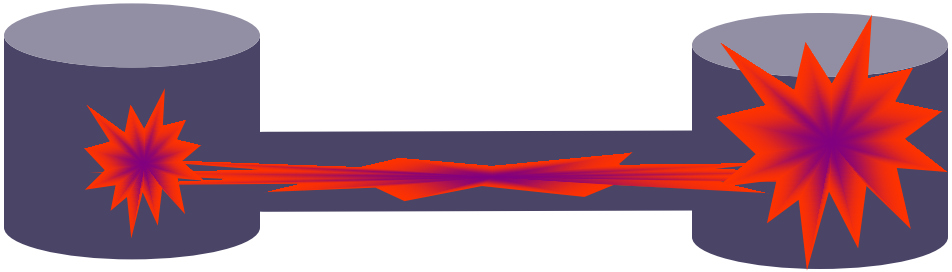
Source: Elkem Metals Co., LP, 2002.

Prevention of Secondary Explosions

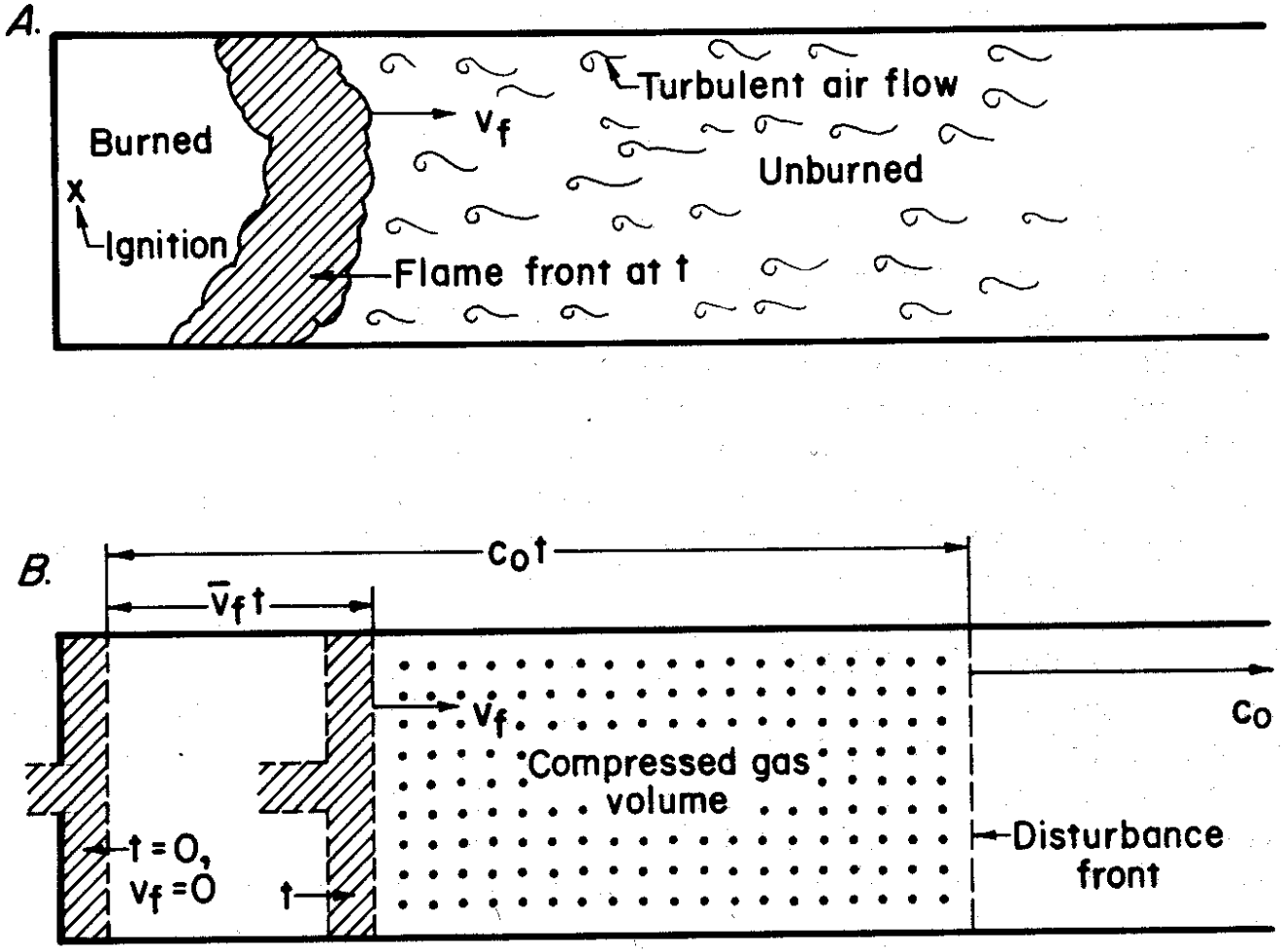
- Proper Design Containment
  - Elimination of one or more of the five parameters
  - Venting
  - Barriers and Location
  - Stop gates
- Housekeeping - KEEP IT CLEAN

Pressure Piling

- Primary Reaction in one containment vessel
- Flame Propagation to secondary containment preceded by the cool pressure wave
- Raises pressure in secondary before flame front arrives
- Secondary containment starts reacting at a high initial pressure creating a higher ending pressure

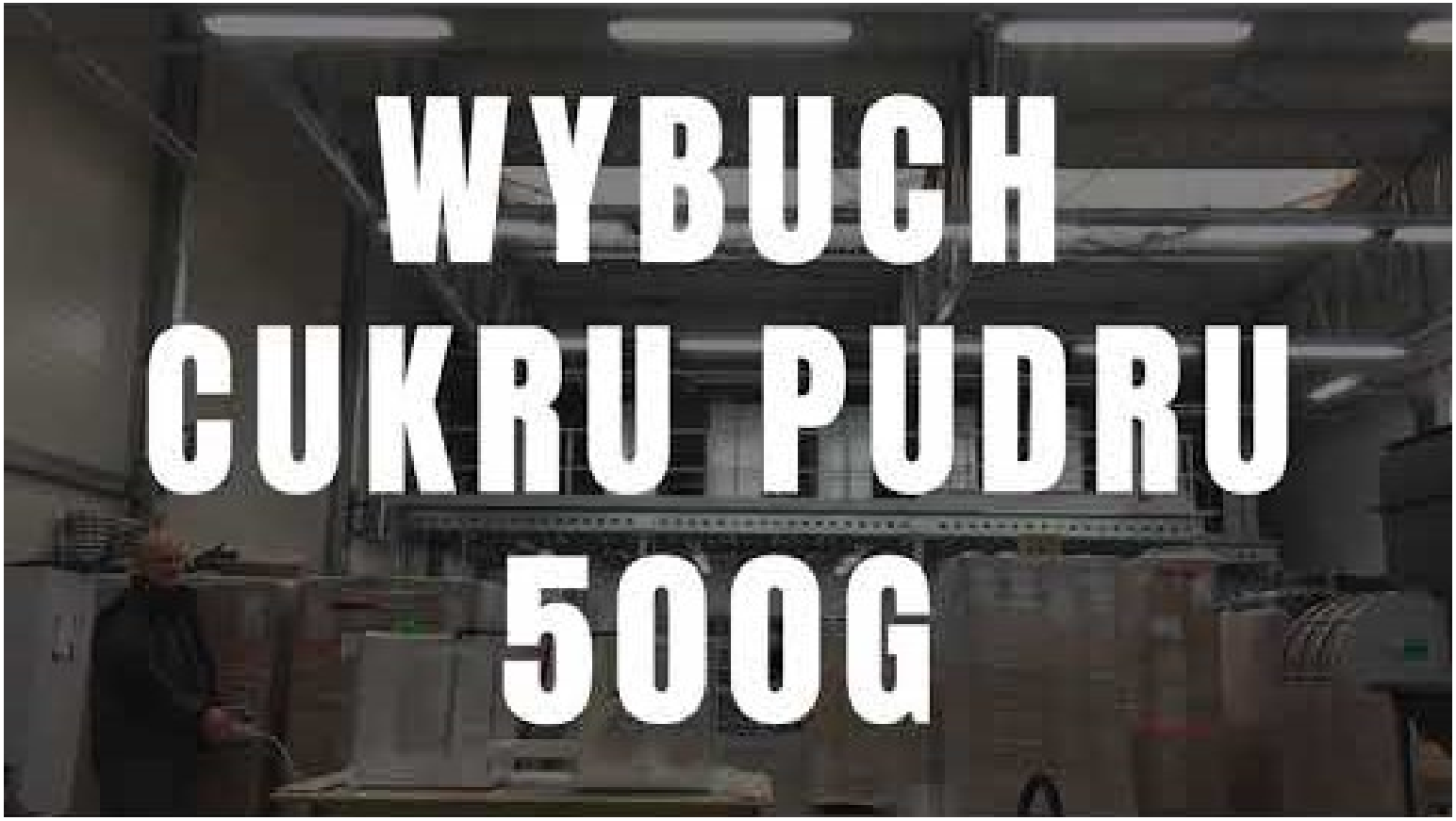


Pressure Piling



Source: Cashdollar, Industrial Dust Explosions, ASTM, 1987.

Pressure Piling Demonstration



Source: Grupa Wolff, www.grupa-wolff.com

Risk Reduction with Human Factors

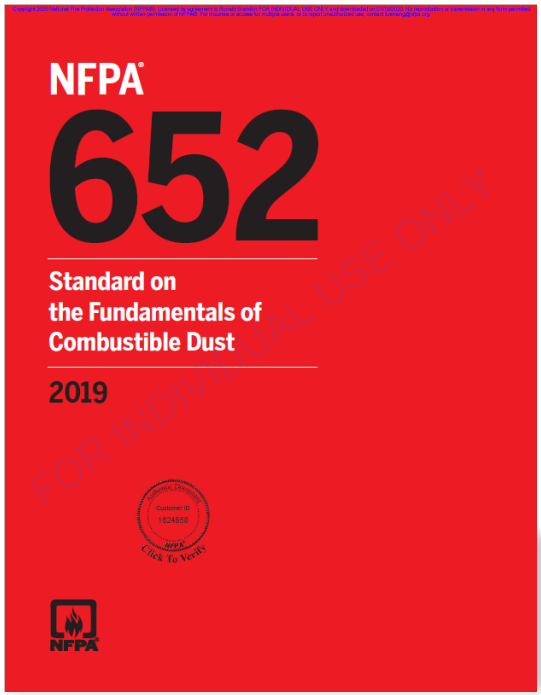
- Operators have the greatest impact on operation safety
- Carefully design human interactions with system
  - Employee knowledge
  - Employee behavior
  - Design of process controls and displays
  - Task analysis
  - Proper job design

Management of Risk

- Hazard Analysis
- Standard Operating Procedures
- Maintenance Operating procedures
- Complete set of written procedures BEFORE turning first switch
- Training
- Audits
- Operator - Maintenance involvement
- Checks and balances by the safety personnel

NFPA 652 Published

- The 652 standard became effective on September 7, 2015, revised in 2019.
  - 3 years of effort.
  - Response to CSB, OSHA and concerns of a lack of an over-arcing methodology to NFPA recommendations on dust fire and explosion prevention.
- Intended to work with commodity specific standards.



Requirement for a DHA

- Chapter 7 of NFPA 652
- Guidance given in Annex A & B of NFPA 652
- Conceptually similar to the OSHA 1910.119 PSM Process Hazards Analysis (PHA) methodology.
- 2019 revision extended the deadline for the dust hazard analysis (DHA) for existing processes and facility compartments to Sept 7, 2020.

DHA - General Requirements

- Responsibility. The owner/operator of a facility where materials that have been determined to be combustible or explosible… shall be responsible to ensure a DHA is completed.
- The requirements shall apply retroactively.
- For existing processes and facility compartments that are undergoing material modification, the owner/operator shall complete DHAs as part of the project. Must be completed within 3 years.
- Must be reviewed and updated every 5 years.

DHA - Criteria

- The DHA shall evaluate the fire, deflagration, and explosion hazards and provide recommendations to manage the hazards in accordance with Section 4.2.
- Qualifications*: The DHA shall be performed or led by a qualified person.
- Documentation: The results of the DHA review shall be documented, including any necessary action items requiring change to the process materials, physical process, process operations, or facilities associated with the process.

DHA - Methodology

- General
  - Identification of safe operating ranges
  - Identification of the safeguards that are in place
  - Recommendation of additional safeguards
- Material Evaluation
  - DHA based on Hazard Identification process described in Chapter 5 of the 652 Std
- Process Systems
  - Potential intended and unintended combustible dust transport between parts of the process system
  - Potential fugitive combustible dust emissions into a building or building compartments
  - Potential deflagration propagation between parts of the process system
- Building or Building Compartments

DHA - Methodology

- **Material Evaluation**
  - DHA based on Hazard Identification process described in Chapter 5 of the 652 Std

DHA - Methodology

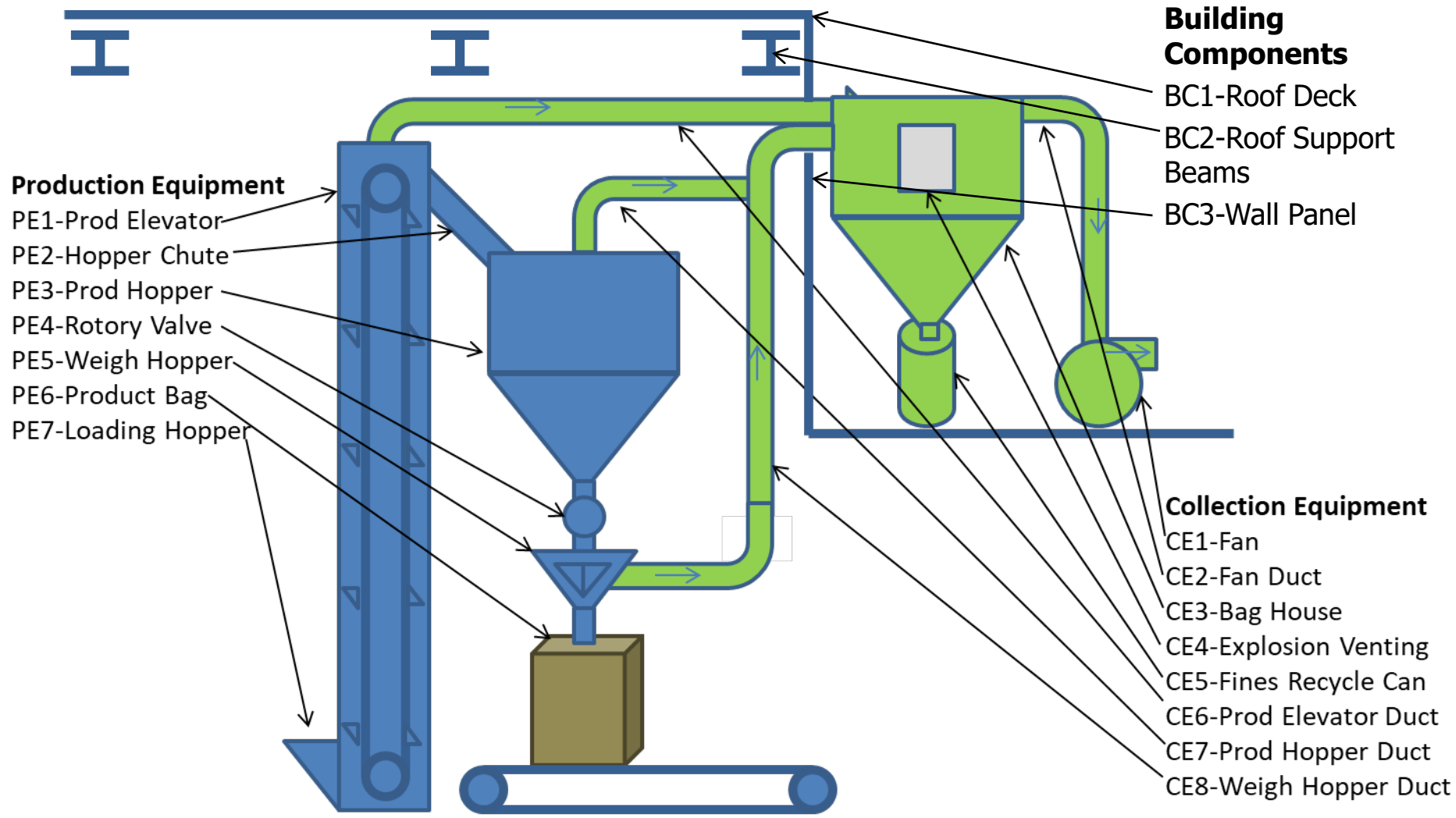
- **Process Systems**
  - Potential intended and unintended combustible dust transport between parts of the process system
  - Potential fugitive combustible dust emissions into a building or building compartments
  - Potential deflagration propagation between parts of the process system

  And:
  - Oxidizing atmosphere
  - Credible ignition source
  - Credible suspension mechanism

DHA - Methodology

- **Building or Building Compartments**
  - The evaluation shall address potential combustible dust migration between buildings or building compartments.
  - The evaluation shall address potential deflagration propagation between buildings or building compartments.
  - The evaluation of dust deflagration hazard in a building or building compartment shall include a comparison of actual or intended dust accumulation to the threshold housekeeping dust accumulation that would present a potential for flash-fire exposure to personnel or compartment failure due to explosive overpressure.
  - Threshold housekeeping dust accumulation levels and nonroutine dust accumulation levels (e.g., from a process upset) shall be in accordance with relevant industry- or commodity-specific NFPA standards.

DHA Example Process: Wood Pellets



Dust Flammability and Explosibility Quantification Example

Testing Lab XYZ Corp
Dust Combustibility and Explosibility Evaluation Report
Material: Fines of wood pelletizing and packaging operation

Table A.5.2.2(b) 1 m^3 Vessel Test Data from Forschungsbericht Staubexplosionen – Agricultural Dusts

Material	Mass Median Diameter (µm)	Minimum Flammable Concentration (g/m^3)	P_{max} (bar)	K_{St} (bar-m/s)	Dust Hazard Class
Wood flour	29	—	10.5	205	2

DHA Example Instrument

Equipment ID No.	Equipment name	Is the pariculate deflagrable (explosive)?	Is the pariculate suspended in air?	Is there sufficient concentration to propagate a flame front?	Are there competent igniters available? (Yes)	What hazard management is in place?	DHA Catergory Assessment
PE1	Production Elevator	Y	Y	Y	Y	Dust Coll	Deflagration Hazard

OSHA Combustible Dust National Emphasis Program

OSHA INSTRUCTION

DIRECTIVE NUMBER: CPL 03-00-008	**EFFECTIVE DATE:** 3/11/08
SUBJECT: Combustible Dust National Emphasis Program (Reissued)	

ABSTRACT

Purpose: This instruction contains policies and procedures for inspecting workplaces that create or handle combustible dusts. In some circumstances these dusts may cause a deflagration, other fires, or an explosion. These dusts include, but are not limited to:

- Metal dust such as aluminum and magnesium.
- Wood dust
- Coal and other carbon dusts.
- Plastic dust and additives
- Biosolids
- Other organic dust such as sugar, flour, paper, soap, and dried blood.
- Certain textile materials

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=DIRECTIVES&p_id=3830

OSHA Regulations Applied to Dust

- A citation under section **5(a)(1) of the OSH Act** (the general duty clause) may be issued for deflagration, explosion or other fire hazards that may be caused by combustible dust within a dust collection system or other containers, such as mixers.
- If dust accumulations create an explosion, deflagration or other fire hazard, then citations will be issued for violations of **1910.22** (housekeeping) paragraph (b), grinding, polishing, and buffing operations.
- If the facility's operations are covered by **1910.94**, Ventilation, then any violations of the standard shall be cited with paragraph (a) of the standard covers abrasive blasting.
- Citations under **1910.119** shall be issued for PSM violations when dust is on PSM list.
- **1910.176(c)** shall be cited for housekeeping violations in storage areas.
- Citations for violations of **1910.263(k)(2)** shall be issued for fire and explosion hazards in sugar and spice pulverizers.
- Housekeeping violations at coal-handling operations covered under **1910.269**.
- Grain Handling Standard Violations cited under **1910.272**
- The hazard communication standard, **1910.1200**, requires all employers to provide information to their employees about the hazardous chemicals to which they are exposed, including chemicals which in the course of normal conditions of use could become combustible dusts

OSHA Combustible Dust Std Update

DOL/OSHA **RIN:** 1218-AC41 **Publication ID:** Fall 2010

Title: Combustible Dust

Abstract: OSHA has commenced rulemaking to develop a combustible dust standard for general industry. The U.S. Chemical Safety Board (CSB) completed a study of combustible dust hazards in late 2006, which identified 281 combustible dust incidents between 1980 and 2005 that killed 119 workers and injured another 718. Based on these findings, the CSB recommended the Agency pursue a rulemaking on this issue. OSHA has previously addressed aspects of this risk. For example, on July 31, 2005, OSHA published the Safety and Health Information Bulletin, "Combustible Dust in Industry: Preventing and Mitigating the Effects of Fire and Explosions." Additionally, OSHA implemented a Combustible Dust National Emphasis Program (NEP) March 11, 2008. However, the Agency does not have a comprehensive standard that addresses combustible dust hazards. OSHA will use the information gathered from the NEP to assist in the development of this rule. OSHA published an ANPRM October 21, 2009. Additionally, stakeholder meetings were held in Washington, DC on December 14, 2009, in Atlanta, GA on February 17, 2010, and in Chicago, IL on April 21, 2010. A webchat for combustible dust was also held on June 28, 2010. The next step in this rulemaking will be to initiate SBREFA in April 2011.

Agency: Department of Labor(DOL)

Priority: Economically Significant

RIN Status: Previously published in the Unified Agenda

Agenda Stage of Rulemaking: Proposed Rule Stage

Major: Yes

Unfunded Mandates: No

CFR Citation: 29 CFR 1910, subpart H (To search for a specific CFR, visit the Code of Federal Regulations.)

Legal Authority: 29 USC 6559(b) 29 USC 657

Legal Deadline: None

Timetable:

Action	Date	FR Cite
ANPRM	10/21/2009	74 FR 54333
ANPRM Comment Period End	01/19/2010	
Stakeholder Meetings	12/14/2009	
Stakeholder Meetings	02/17/2010	
Stakeholders Meetings	03/09/2010	75 FR 10739
Initiate SBREFA	04/00/2011	

Regulatory Flexibility Analysis Required: Undetermined

Government Levels Affected: Undetermined

Federalism: No

Included in the Regulatory Plan: No

RIN Data Printed in the FR: No

Agency Contact:
Dorothy Dougherty
Director, Directorate of Standards and Guidance
Department of Labor

Latest Rulemaking News:
May 2015: OSHA's Spring 2015 regulatory agenda upgraded the combustible dust standard from a "Long-term action" to the "Pre-rule stage", with the Small Business Review (SBREFA) panel expected in February 2016

Significant CSB Investigations

- **West Pharmaceutical Services**, Kinston, NC, DOA: Jan 29, 2003
- **Hayes Lemmerz Intl, Inc**., Huntington, IN, DOA: Oct 29, 2003
- **Imperial Sugar** refinery, Port Wentworth, GA, DOA: Feb 7, 2008
- **AL Solutions, Inc**., New Cumberland, WV, DOA Dec 9, 2010

West Pharmaceutical Summary

West Pharmaceutical Services Dust Explosion and Fire

Location: Kinston, NC
Accident Occurred On: 01/29/2003
Final Report Released On: 09/23/2004
Accident Type: Combustible Dust Explosion and Fire
Company Name: West Pharmaceutical Services

STATISTICS

Total # of Recommendations	9
Total # of Open Recommendations	0
Total # of Closed Recommendations	9
Total % of Open 0 *vs. Closed* 100	

- Revise policies and procedures for new material safety reviews.
- Develop and implement policies and procedures for safety reviews of engineering projects.
- Improve hazard communication programs so that the hazards of combustible dust are clearly identified and communicated to the workforce.
- Amend Chapter 13, Section 1304, of the International Fire Code (as adopted by the North Carolina Fire Code) to make compliance with NFPA 654, Standard for the Prevention of Fire and Dust Explosions From the Manufacturing, Processing, and Handling of Combustible Particulate Solids, mandatory.

Hayes Lemmerz Intl Inc. Summary

Hayes Lemmerz Dust Explosions and Fire

FINAL REPORT: Final Investigation Report

Location: Huntington, IN
Accident Occurred On: 10/29/2003
Final Report Released On: 09/27/2005
Accident Type: Combustible Dust Explosion and Fire
Company Name: Hayes Lemmerz

STATISTICS

Total # of Recommendations	20
Total # of Open Recommendations	0
Total # of Closed Recommendations	20
Total % of Open 0 *vs. Closed* 100	

- Develop and implement a means of handling and processing aluminum chips that minimizes the risk of dust explosions.
- Implement a program to provide regular training for all facility employees on the fire and explosion hazards of aluminum dust.
- Develop and implement policies and procedures for conducting engineering, hazard, and management of change (MOC) reviews of plant projects and modifications to support systems such as chip processing.
- Implement a program to conduct management reviews of incidents and near-miss incidents, including duct fires and dust flashes.

Imperial Sugar Company Summary

Imperial Sugar Company Dust Explosion and Fire
Location: Port Wentworth, GA
Accident Occurred On: 02/07/2008
Final Report Released On: 09/24/2009
Accident Type: Combustible Dust Explosion and Fire
Company Name: Imperial Sugar Company

STATISTICS

Total # of Recommendations	11
Total # of Open Recommendations	1
Total # of Closed Recommendations	10
Total % of Open 9 *vs. Closed* 91	

- Apply the following standards to the design and operation of the new Port Wentworth facility: NFPA 61, 499, 654, NFPA Handbook, Electrical Installations in Hazardous Locations, NFPA 70 - Article 500 - Hazardous (Classified) Locations. Review all Imperial Sugar locations for the same.
- Implement a corporate-wide comprehensive housekeeping program to control combustible dust accumulation that will ensure sugar dust, cornstarch dust, or other combustible dust does not accumulate to hazardous quantities on overhead horizontal surfaces, packing equipment, and floors.
- Add specific combustible dust inspection requirements and metrics to the Food Contact Packaging Facility audit procedures.

CSB Recommendations to OSHA

Combustible Dust Hazard Investigation

FINAL REPORT: Combustible Dust Hazard Study

Location: Washington, DC
Accident Occurred On: 10/01/2004
Final Report Released On: 11/09/2006
Accident Type: Combustible Dust Explosion and Fire

STATISTICS

Total # of Recommendations	6
Total # of Open Recommendations	2
Total # of Closed Recommendations	4
Total % of Open 33 *vs. Closed* 67	

- Issue a standard designed to prevent combustible dust fires and explosions in general industry. Base the standard on current NFPA dust explosion standards (including NFPA 654 and NFPA 484), and include at least:
  - hazard assessment,
  - engineering controls,
  - housekeeping,
  - building design,
  - explosion protection,
  - operating procedures, and
  - worker training.
- While a standard is being developed, identify manufacturing industries at risk and develop and implement a national Special Emphasis Program (SEP) on combustible dust hazards in general industry.

NFPA Standards

- NFPA 61, Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities, latest edition.
- NFPA 68, Standard on Explosion Protection by Deflagration Venting, latest edition.
- NFPA 69, Standard on Explosion Prevention Systems, latest edition.
- NFPA 484, Standard for Combustible Metals, latest edition.
- NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids, latest edition.
- NFPA 664, Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities, latest edition.

Prevention of a Dust Explosion

Summary

- Elimination of dust explosion parameters
- Engineering out the hazard
- Human Factors
- Risk reduction through management systems

Combustible Dust Event Response

Source: www.statrer911.com & Kam Productions

Damage Control: Considerations Regarding Explosive Dust Fires

- Develop detailed emergency response plans in advance of system start-up
- Train and retrain on the plans
- Execute the plans during actual emergencies with patients, risk –based decision making and diligence

Damage Control: Considerations Regarding Explosive Dust Fires

Probable scenarios:

1) Smoldering or unreacted pile of dust remaining after an explosion
2) Smoldering pile of dust not yet involved in an explosion.

Damage Control: Considerations Regarding Explosive Dust Fires

- Important Considerations for fighting dust fires
  - De-energize all energy sources
  - Field assessment of structure
  - Current level of dust suspension
  - Potential for primary or secondary explosions
  - Determine proper fire fighting media
  - **Do not** use high pressure streams of water directed at piles of dust

Key Point Summary

- Understand your materials characteristics through proper testing
- Seek help from dust explosion experts
- Seek experienced design companies for engineering
- Develop management systems to control risk
- Maintain good housekeeping
- Audit aggressively to verify adherence to risk control practices
- Have an effective emergency plan

Sources of Help

- Fike Explosion Protection Systems
- Fenwal Safety Systems
- References in the Proceedings Paper
- Google
- OSHA – Combustible Dust Guidance page
- NIOSH
- MSHA
- CSB – Combustible Dust Safety page
- NFPA

Dust Hazard Consulting Resources

- ERM- www.erm.com
- Chilworth - www.chilworth.com
- Fike - www.fike.com
- FM Global - www.fmglobal.com
- Exponent - www.exponent.com

Important References & Resources

Brandon, R. C., & Machir, D. S. (2002). Prevention and Control of Dust Explosions in Industry. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

Hertzberg, M., & Cashdollar, K. L. (1987). Introduction to dust explosions. Industrial dust explosions. West Conshohocken, PA: American Society for Testing and Materials (ASTM), Special Technical Publication (STP), 958, 5-32.

Eckhoff, R. (2003). *Dust explosions in the process industries: identification, assessment and control of dust hazards*. Gulf professional publishing.

Chemical Safety Board (CSB). 2006. Combustible Dust Hazard Study: Investigation report for dust accidents in U.S., Washington, D.C.

ASTM E1226, 2012a. Standard Test Method for Explosibility of Dust Clouds.

ASTM E1515, 2007. Standard Test Method for Minimum Explosible Concentration of Combustible Dusts.

NFPA 61, Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities, latest edition.

NFPA 68, Standard on Explosion Protection by Deflagration Venting, latest edition.

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NFPA 484, Standard for Combustible Metals, latest edition.

NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids, latest edition.

NFPA 664, Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities, latest edition.

FMGlobal, 2014. Loss Prevention Datasheet 7-76: Prevention and Mitigation of Combustible Dust Explosions and Fires. FMGlobal, Johnson RI.

Powder and Bulk Engineering magazine:	www.powderbulk.com
OSHA Combustible Dust Safety & Health page:	www.osha.gov/dsg/combustibledust/guidance.html
CSB Combustible Dust Hazard Investigation:	www.csb.gov/combustible-dust-hazard-investigation/

Questions?

Thank You!

Contact Chet Brandon at:

Email: chet.brandon@LeadingEHS.com
Cell: 316.650.9583
Web: LeadingEHS.com